ONLYIAS
BY PHYSICS WALLAH

UPSC WALLAH

ENVIRONMENT AND ECOLOGY

COMPREHENSIVE LEARNING SERIES FOR PRELIMS AND MAINS

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A plethora of UPSC Study Material is available in the market but PW ONLY IAS professionals are continuously working to provide the supreme quality study material for our UPSC students.

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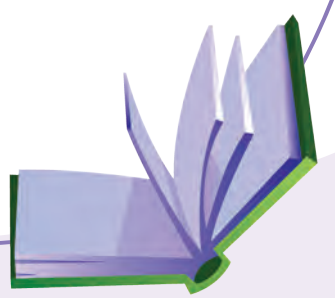
The main objective of the study material is to provide short, crisp, concise and high-quality content to our students.

BOOK FEATURES

- Holistic coverage of topics, strictly as per exam syllabus
- One-stop solution for subject wise coverage
- Intensive use of Maps, Diagrams, Flowcharts and Timelines for quick understanding and revision
- Thinking Points in and as ‘Ignite Your Mind’
- Updated with latest current affairs and data



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Basics of Ecology and Environment

1

INTRODUCTION

Ecology, the study of the interactions between organisms and their environment, provides invaluable insights into the intricate balance of life on Earth. In this chapter, we delve into the fundamental principles of ecology and explore the various levels of organization within ecosystems. From the origin of life forms to the dynamics of ecological communities, we examine the interconnectedness of living organisms and their surroundings. Additionally, we investigate the concept of biodiversity and its importance in maintaining ecosystem health and resilience. By understanding the complexities of ecology, we gain a deeper appreciation for the natural world and the urgent need to protect and preserve it for future generations.

History of Life Forms on Earth

The history of life on Earth spans billions of years and is divided into several major geological and biological eras. Here is a brief overview:

- **Precambrian Eon (4.6 billion years ago to 541 million years ago):**
  - The Precambrian Eon encompasses the vast majority of Earth's history, beginning with the formation of the planet and extending up to the start of the Cambrian Period. During this time, Earth underwent significant geological and atmospheric changes, and the **first life forms appeared.** The Precambrian includes the Archean and Proterozoic Eons.
- **Palaeozoic Era (541 million years ago to 252.17 million years ago):**
  - The Paleozoic Era is characterized by the **emergence and diversification of complex multicellular life forms, including fish, plants, insects, and early land vertebrates.** Major events during this era include the Cambrian Explosion, the colonization of land by plants and animals, and the development of forests and swamps. The Paleozoic ended with the **largest mass extinction event in Earth's history, the Permian-Triassic extinction.**
- **Mesozoic Era (252.17 million years ago to 66 million years ago):**
  - The Mesozoic Era is often referred to as the **"Age of Dinosaurs."** It saw the dominance of reptiles, including dinosaurs, pterosaurs, and marine reptiles. The Mesozoic also witnessed the evolution of birds, mammals, and flowering plants. The era ended with another major mass extinction event, the **Cretaceous-Paleogene extinction, which led to the extinction of non-avian dinosaurs and many other species.**

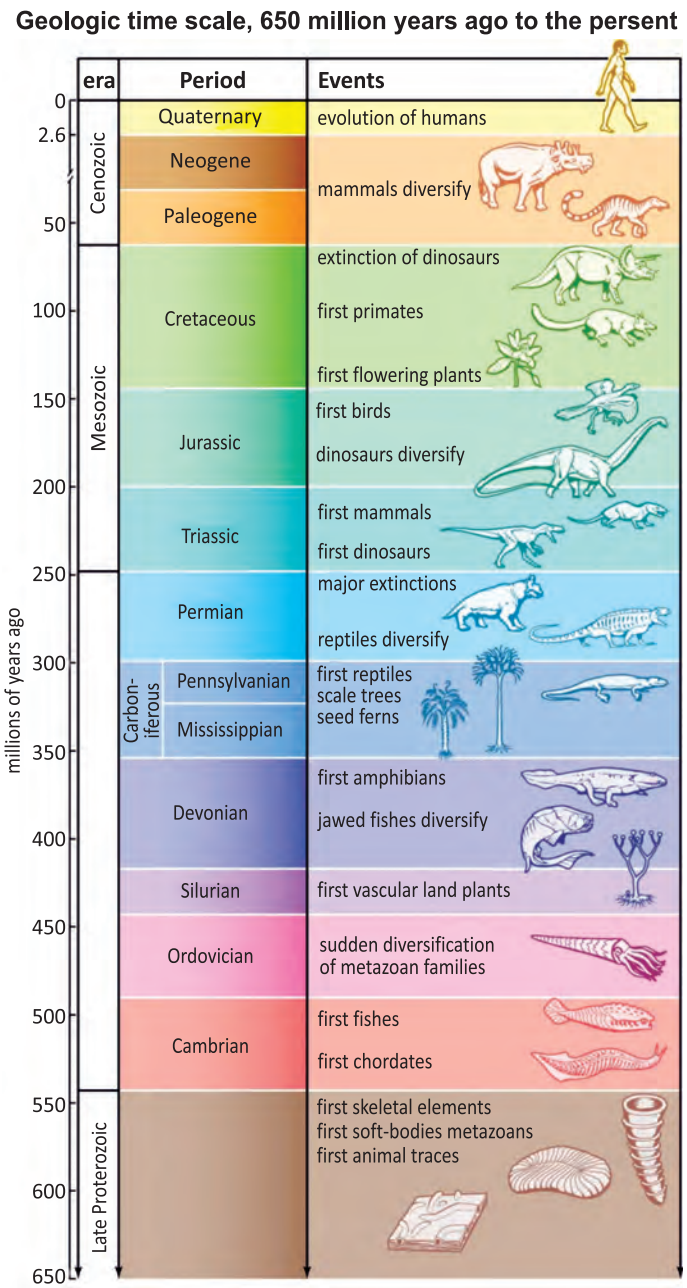

Fig. 1.1: Evolution of Lifeform

- **Cenozoic Era (66 million years ago to present):**
  - The Cenozoic Era is divided into the Paleogene, Neogene, and Quaternary periods. It is characterized by the **diversification of mammals, birds, and flowering plants.** Major events during this era includes the rise of mammals to ecological dominance after the extinction of dinosaurs, the evolution of hominids and eventually humans, and the development of ice ages during the Quaternary Period, **which extends to present time.**

Throughout Earth's history, life has undergone numerous evolutionary innovations, adaptations, and mass extinction events. The study of the history of life on Earth, known as palaeontology provides insights into the evolution of biodiversity and the processes that have shaped the planet's ecosystems over time.

ECOLOGY

Ecology is the **scientific study of the interactions between living organisms and their environment.** It encompasses the relationships between living organisms (biotic factors) and their physical surroundings (abiotic factors), including other organisms, the atmosphere, water, soil, and climate.

- **The term "ecology" was coined by the German zoologist, Ernst Haeckel, in 1866.**
- Ecology examines how organisms interact with each other and their environment at various levels of organization, from individual organisms to populations, communities, ecosystems, and the biosphere as a whole.
- It explores topics such as energy flow, nutrient cycling, population dynamics, species distributions, and the influence of factors like competition, predation, symbiosis, and environmental change on ecosystems.
- Ecologists study ecosystems of all types, from terrestrial to aquatic, and from natural to human-altered environments. They use a variety of methods, including field observations, experiments, mathematical modeling, and remote sensing, to understand the complexities of ecological systems and to address pressing environmental issues such as habitat loss, biodiversity decline, climate change, and pollution.

Scope of Ecology

The scope of ecology is vast and encompasses the study of interactions between organisms and their environment at various levels of organization, from the individual to the global scale.

- Ecology explores the distribution and abundance of organisms, the dynamics of populations and communities, the flow of energy and nutrients through ecosystems, and the functioning of the biosphere as a whole.
- It encompasses a wide range of sub-disciplines, including organismal ecology, population ecology, community ecology, ecosystem ecology, landscape ecology, global ecology, and conservation ecology.
- The scope of ecology extends to understanding the impacts of human activities on ecosystems and biodiversity, informing conservation and management strategies, and addressing pressing environmental challenges such as climate change, habitat loss, and pollution.
- Overall, the scope of ecology is interdisciplinary, dynamic, and essential for understanding the complex interactions between living organisms and their environment.

Principles of Ecology

The principles of ecology are fundamental concepts and patterns that govern the relationships and interactions between organisms and their environment. These principles provide a framework for understanding the structure and function of ecosystems, as well as the distribution and abundance of organisms within them. Some key principles of ecology include:

- **Interdependence:** Organisms within an ecosystem are interconnected and depend on each other for resources such as food, water, shelter, and oxygen. Changes in one part of the ecosystem can have ripple effects throughout the system.
- Some basic ideas regarding the interactions between the trophic levels in a natural ecosystem were proposed by **R. L. Lindeman in 1942.**
  - **Principle 1:** The likelihood that organisms at a given trophic level will solely rely on the trophic level before them diminishes with increasing distance between the organisms and the initial energy source.
  - **Principle 2:** The relative energy loss from respiration increases with increasing trophic level because species at higher trophic levels, which are generally larger in size, must move and exert more energy to obtain food. As a result, more energy is lost from respiration.
  - **Principle 3:** Predator activity increases with trophic level, as species occupying higher trophic levels tend to exhibit more specialized dietary preferences. Predators often display specific prey preferences, which can result in a more selective utilization of their food supply compared to organisms at lower trophic levels.
  - **Principle 4:** Because organisms at progressively higher trophic levels are generalist feeders who obtain their energy from a variety of sources and make better use of the food that is available to them, they are generally less discrete than organisms at lower trophic levels.
  - **Principle 5:** Food chains are typically quite short. Since species at higher trophic levels tend to be less discrete and energy loss increases with increasing trophic level, four vertical links are a common maximum.

- **Energy Flow:** Energy flows through ecosystems in a one-way direction, typically entering as sunlight and being converted into chemical energy by photosynthesis. This energy is then transferred through the ecosystem as organisms consume and are consumed by others, with energy being lost as heat at each step.
- **Nutrient Cycling:** Nutrients such as carbon, nitrogen, and phosphorus cycle through ecosystems, moving between living organisms, the soil, water, and the atmosphere. Decomposers play a crucial role in breaking down organic matter and releasing nutrients back into the environment for reuse by plants and other organisms.
- **Biodiversity:** Biodiversity refers to the variety of species and genetic diversity within an ecosystem. High biodiversity is often associated with ecosystem resilience and stability, as diverse ecosystems can better withstand environmental disturbances and provide a range of ecosystem services.
- **Succession:** Ecological succession is the process by which communities of organisms change over time in response to disturbances or changes in environmental conditions. **Disturbances can include events such as fire, floods or human activity. Primary succession** occurs in newly formed habitats with no previous life, while **Secondary succession** occurs in habitats that have been disturbed but still contain soil and seeds.
- **Limiting Factors:** Limiting factors are environmental factors that restrict the growth, abundance, or distribution of organisms within an ecosystem. These factors can include physical factors such as temperature, water availability, and sunlight, as well as biological factors such as competition, predation, and disease.
- **Carrying Capacity:** Carrying capacity is the maximum population size that an ecosystem can sustain over the long term without causing environmental degradation or resource depletion. It is determined by factors such as resource availability, environmental conditions, and the interactions between species.
- **Habitat and Niche:** Every organism has a specific habitat, or the physical environment in which it lives, as well as a niche, or its role and position within the ecosystem. The niche includes the organism's interactions with other species and its use of resources.

These principles provide a framework for understanding the complex dynamics of ecological systems and are essential for addressing pressing environmental challenges such as habitat loss, biodiversity decline, climate change, and pollution.

Environment and its Component

The environment is everything around an organism that affects it throughout its life. It includes all **living** and **non-living** things that influence the events around the organism.

Biotic and Abiotic Components

Biotic Components	Abiotic Components
Plants	Sunlight
Animals	Temperature & Heat flow
Bacteria	Water
Fungi	Air and Atmospheric gases
Humans	Soil
Microorganisms	Geological substratum

Organisms rely on the environment and other organisms for food, energy, water, oxygen, shelter, and other necessities. The relationship and interaction between organisms and their environment is highly complex, involving both living (biotic) and non-living (abiotic) components. The environment is always changing, with both living and non-living factors constantly in flux.

Ecological Hierarchy

Ecological hierarchy refers to the organization of biological systems into levels of increasing complexity, with each level consisting of interacting components that contribute to the functioning of the whole system. These hierarchical levels range from individual organisms to the entire biosphere. The ecological hierarchy typically includes the following levels:

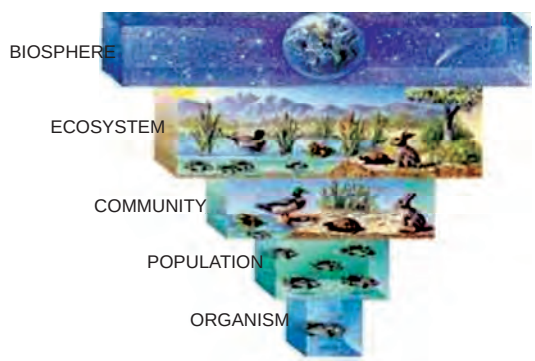

Fig. 1.2: Ecological Hierarchy

- **Individual Organism:** At the lowest level of the hierarchy are individual organisms, such as plants, animals, fungi, and microorganisms. These organisms interact with each other and their environment, exhibiting behaviors and physiological processes that contribute to their survival and reproduction.
- **Population:** A population consists of a **group of individuals of the same species** living in the same area and interacting with one another. Population ecology focuses on understanding the dynamics of populations, including factors such as birth rates, death rates, immigration, emigration, and population growth.
  - **Example** A population of white-tailed deer consists of multiple individuals of the same species living in a forest ecosystem. Population ecology studies the dynamics of this population, including birth rates, death rates, migration patterns, and population growth over time.

- **Community:** A community is composed of **multiple populations of different species** living in the same area and interacting with one another. Community ecology examines the interactions between species within a community, including competition, predation, mutualism, and other forms of species interactions.
- **Types of Communities:**
  - **Terrestrial Communities:** These communities occur on land and can include forests, grasslands, deserts, tundra, and other terrestrial habitats.
  - **Aquatic Communities:** These communities occur in water bodies such as oceans, lakes, rivers, streams, ponds, and wetlands.
  - **Microbial Communities:** These communities consist of microorganisms such as bacteria, fungi, algae, and protists, which interact with one another in various environments, including soil, water, and the human body.
  - **Example** A forest community in the Pacific Northwest includes multiple populations of trees, shrubs, herbaceous plants, fungi, insects, birds, mammals, and other organisms interacting with one another. Community ecology examines the relationships and interactions between these species, such as competition for resources, predation, and mutualistic interactions.
- **Ecosystem:** An ecosystem includes all living organisms (biotic factors) in a particular area and their physical environment (abiotic factors), such as soil, water, air, and climate. Ecosystem ecology studies the flow of energy and nutrients through ecosystems and the interactions between organisms and their environment.
  - **Example** A coral reef ecosystem includes a diverse array of living organisms such as corals, fish, algae, invertebrates, and microorganisms, along with their physical environment of water, sunlight, temperature, and substrate. Ecosystem ecology studies the flow of energy and nutrients within the coral reef ecosystem and the interactions between organisms and their abiotic environment.

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A Hierarchy of Existence: Unveiling the Ladder of Life

From solitary individuals to thriving biomes, how do different levels of organization, like populations, communities, and ecosystems, interconnect to form the grand symphony of life?

- **Biome:** A biome is a large-scale ecological region characterized by distinct climate, vegetation, and animal life. Biomes are defined by factors such as temperature, precipitation, and soil type. Examples of biomes include tropical rainforests, deserts, grasslands, and tundra. The biosphere's terrestrial portion can be divided into vast areas known as biomes, each of which has its own distinct climate, vegetation, animal life, and general type of soil. Every biome is unique. The limits of a biome and the variety of plants and animals that can be found there are determined by the climate. Temperature and precipitation are the two main climatic variables.

Types of Biomes

Biome	Location	Climate	Vegetation	Examples of Animals
Tropical Rainforest	Near the equator	Hot and humid	Dense trees, diverse plant life	Monkeys, birds, reptiles
Temperate Deciduous Forest	Temperate regions	Moderate rainfall	Deciduous trees, mixed forests	Deer, bears, squirrels
Taiga (Boreal Forest)	Subarctic regions	Cold winters, short summers	Coniferous trees, evergreen forests	Wolves, moose, lynx
Temperate Grassland	Temperate regions	Seasonal temperature variations	Grasses, herbaceous plants	Bison, prairie dogs, gazelles
Desert	Arid regions	Low precipitation	Sparse vegetation, succulent plants	Camels, snakes, lizards
Tundra	Polar regions	Permafrost, cold temperatures	Low-growing vegetation, mosses	Caribou, musk oxen, polar bears
Savanna	Tropical regions	Wet and dry seasons	Grasses, scattered trees and shrubs	Elephants, giraffes, lions
Chaparral	Mediterranean climates	Hot, dry summers, mild winters	Shrubs, small trees	Coyotes, rabbits, lizards

- **Biosphere:** The biosphere refers to the zone on Earth where life exists. It encompasses all living organisms, from the deepest ocean trenches to the highest mountain peaks, and includes various ecosystems such as forests, grasslands, deserts, oceans, and freshwater bodies. The biosphere interacts with the atmosphere, hydrosphere, and lithosphere, forming a complex web of relationships that regulate Earth's climate, nutrient cycles, and biodiversity.

- **Atmosphere:** The layer of gasses surrounding the Earth, providing the air necessary for life. It consists mainly of nitrogen, oxygen, carbon dioxide, and other trace gases.
- **Hydrosphere:** The water component of the Earth, including oceans, rivers, lakes, glaciers, and groundwater. Water is essential for all forms of life and plays a vital role in shaping ecosystems.
- **Lithosphere:** The solid outer layer of the Earth, which includes the crust and upper mantle. It provides the land surface and substrate for terrestrial ecosystems.

Understanding the ecological hierarchy helps ecologists study and analyze complex ecological systems at different scales, from individual organisms to global processes, and provides insights into the dynamics and functioning of ecosystems and the interactions between organisms and their environment.

ECOSYSTEM

An ecosystem refers to a dynamic system comprising living organisms, such as plants and animals, interacting with their physical surroundings, including air, water, soil, and sunlight. These interactions involve the flow of energy and cycling of nutrients, contributing to the maintenance of life and ecological balance within a specific area or habitat.

- It encompasses all living organisms (biotic factors) in a particular area, as well as non-living components (abiotic factors) such as soil, water, sunlight, and climate. Ecosystems can vary greatly in size and complexity, ranging from small ponds to vast forests or even entire biomes like deserts or oceans.
- They function as self-sustaining units where energy and nutrients flow through various interconnected components, supporting the survival and growth of organisms within them. Ecosystems play a crucial role in maintaining the balance of life on Earth and provide essential services such as air and water purification, nutrient cycling, and habitat for biodiversity.

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The Ecosystem: A Theatre of Life's Drama

What defines an ecosystem? Is it merely a stage or a complex interplay of actors, from producers to decomposers, each playing a crucial role in the grand ecological play?

Structure of Ecosystem

The physical characteristics of the environment, such as the quantity and distribution of nutrients in a given habitat, and the organisms that inhabit it are essentially described by the structure of an ecosystem. The structure of an ecosystem refers to its organisation and components, which can be categorised into abiotic and biotic components.

Abiotic Components

Abiotic components are the **non-living** factors that shape the structure of ecosystems. These include physical factors such as climate, soil, water, and topography, as well as chemical factors like nutrients and pH levels. Abiotic components profoundly influence the distribution and abundance of organisms within ecosystems.

- **Physical Environment:** This includes factors such as climate (temperature, precipitation, humidity), topography (terrain, elevation), sunlight, soil, air and water availability. These physical factors determine the habitat suitability for various organisms and influence their distribution and abundance within the ecosystem.

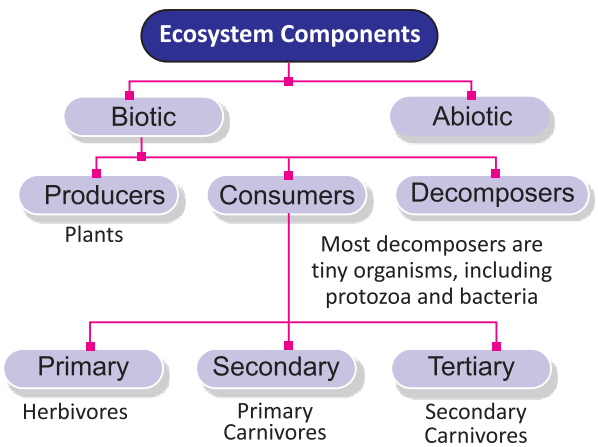

Fig. 1.3: Components of Ecosystem

Biotic Components

The biotic components of ecosystem structure encompass all living organisms within an ecosystem, including producers, consumers, decomposers, and transformers. These organisms interact with each other and their environment, shaping the structure and function of ecosystems.

- **Producers:** Producers, such as plants, algae, and some bacteria, are autotrophic organisms capable of synthesizing organic molecules from inorganic substances through photosynthesis or chemosynthesis. They form the base of the food chain and provide energy and nutrients for other organisms.
  - In the terrestrial ecosystem, producers are basically herbaceous and woody plants, while in aquatic ecosystems producers are various species of microscopic algae.
- **Consumers:** Consumers are heterotrophic organisms that obtain energy and nutrients by consuming other organisms. They can be classified into different trophic levels, including
  - primary consumers like herbivores, which feed mainly on plants eg-cow, rabbit etc.
  - secondary consumers like carnivores, which feed on primary consumers or omnivores.

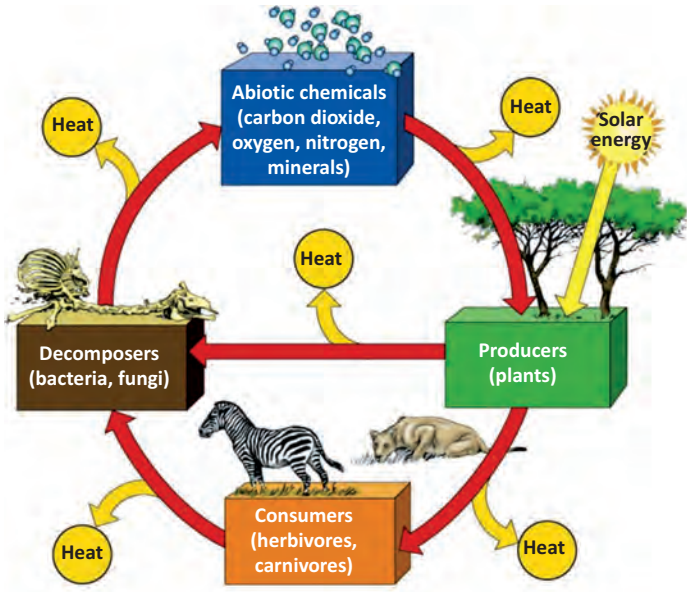

Fig. 1.4: Ecosystem

- tertiary consumers like top predators, which feed on secondary consumers eg-lion, tiger etc.

❑ **Decomposers:** Decomposers, including bacteria, fungi, and detritivores, break down organic matter into simpler substances through the process of decomposition. They play a crucial role in nutrient recycling by decomposing dead organisms and organic waste, releasing nutrients back into the soil or water for uptake by plants. **Earthworms and certain soil organisms (such as nematodes and arthropods) are detritus feeders and help in the decomposition of organic matter and are called detritivores.**

The interactions and relationships among these abiotic and biotic components determine the structure, dynamics, and functioning of an ecosystem, influencing processes such as energy flow, nutrient cycling, and species interactions.

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A Tapestry Woven from Biotic and Abiotic Threads:
Beyond the living and non-living, is there a hidden language spoken by the environment? Delve into the interplay between biotic and abiotic components and how they shape the ecological tapestry.

Difference Between Ecology, Environment, and Ecosystem

Ecology, environment, and ecosystem are interconnected concepts studying living organisms and their surroundings. While ecology focuses on interactions, the environment encompasses broader surroundings, and the ecosystem integrates both biotic and abiotic components in a defined area. However, these three look similar but they have many differences.

Difference between Ecology, Environment, Ecosystem

Aspect	Ecology	Environment	Ecosystem
Definition	Study of interactions between organisms and their environment.	Surroundings in which organ-isms live and interact.	An ecosystem is a structural and functional unit of ecology where the living organisms interact with each other and the surrounding environment.
Focus	Interactions between organisms and their biotic and abiotic surroundings.	Overall surroundings, including physical, biological, and social factors.	Interactions between biotic and abiotic components within a specific area.
Scale	Can occur at various scales, from individual organisms to global systems.	Can refer to local, regional, national, or global contexts.	Typically refers to a specific, delimited area or habitat.
Components	Includes both biotic (living) and abiotic (non-living) factors.	Encompasses physical (air, water, soil), biological (plants, animals), and cultural aspects.	Comprises biotic (plants, animals, microorganisms) and abiotic (soil, water, air) components
Example	Study of predator-prey interactions in a forest ecosystem.	Consideration of pollution levels in a city.	Examination of nutrient cycling in a freshwater lake.
Emphasis	Emphasizes relationships between organisms and their environment.	Focuses on the overall condition and quality of sur-roundings.	Highlights the interconnectedness of living organisms and their physical surroundings.

Classification of Ecosystems

Ecosystems can be classified based on various criteria, including their geographical location, dominant vegetation, climate, and other environmental factors. Some common classifications of ecosystems are follows:

❑ **Terrestrial Ecosystems:**

- **Forest Ecosystems:** Consisting of trees and various understory plants, forests can be further categorized into tropical, temperate, and boreal forests.
- **Grassland Ecosystems:** Characterized by grasses and herbaceous plants, grasslands include prairies, savannas, and steppes.

- **Desert Ecosystems:** Found in arid regions with low precipitation, deserts feature specialized flora and fauna adapted to survive in extreme conditions.
- **Tundra Ecosystems:** Located in polar regions, tundras have low temperatures and a short growing season, with vegetation including mosses, lichens, and small shrubs.

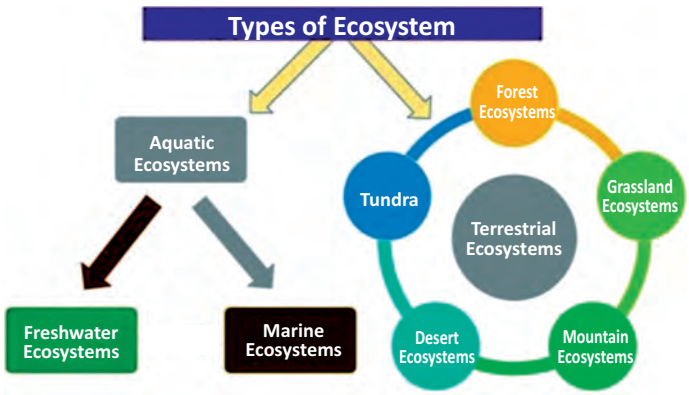

Fig. 1.5: Types of Ecosystem

❑ **Aquatic Ecosystems:**
- **Freshwater Ecosystems:** Including lakes, rivers, ponds, and wetlands, freshwater ecosystems support diverse aquatic life such as fish, amphibians, and waterfowl.
- **Marine Ecosystems:** Found in oceans and seas, marine ecosystems range from shallow coastal areas to deep oceanic zones, supporting various organisms like corals, fish, marine mammals, and plankton.

❑ **Based on Human Influence:**
- **Natural Ecosystems:** Those largely unaffected by human activities.
- **Anthropogenic Ecosystems:** Altered by human activities, including urban areas, agricultural lands, and industrial zones.

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Building Blocks of Life: From Individuals to Biomes

How do seemingly disparate entities like a lone tree, a bustling coral reef, and a vast desert ecosystem come together to form a magnificent tapestry of life?

Ecosystem Services

Ecosystem services are the benefits that humans derive from the natural environment and ecosystems. These services are essential for human well-being and are classified into four main categories:

❑ **Provisioning Services:** These are the tangible products that ecosystems provide, including food, water, timber, fiber, medicinal plants, and genetic resources. For example, forests provide timber and wood products, while rivers and lakes offer fish as a source of food.

❑ **Regulating Services:** Ecosystems regulate various processes and conditions in the environment, such as climate regulation, water purification, pollination, and natural hazard mitigation. Wetlands, for instance, act as natural water filters, improving water quality by trapping pollutants and sediments.

❑ **Supporting Services:** These services are necessary for the production of all other ecosystem services. Examples include soil formation, nutrient cycling, and photosynthesis, which provide the foundation for other ecosystem functions and services.

❑ **Cultural Services:** Ecosystems also provide cultural and recreational benefits to humans, including aesthetic enjoyment, spiritual and cultural significance, tourism, and recreational activities such as hiking, birdwatching, and nature photography. National parks and scenic landscapes exemplify areas valued for their cultural ecosystem services.

Ecosystem services play a vital role in sustaining human societies and economies, and they contribute to various aspects of human well-being, including food security, clean air and water, climate resilience, and cultural identity. Recognizing the importance of ecosystem services is crucial for sustainable development and effective environmental management.

Ecotone

An ecotone is a transitional area or zone where two or more distinct ecosystems or biomes meet and interact. It is characterized by a blend of ecological characteristics from each adjacent ecosystem, resulting in unique environmental conditions and species compositions.

Characteristics

❑ Ecotones can vary in width, from narrow boundaries to broader transition zones.

❑ It has the conditions intermediate to the adjacent ecosystems. Hence it is a zone of tension.

❑ It is **linear** because it displays a gradual increase in the species composition of one incoming community and a concurrent reduction in the species composition of the other outgoing neighboring community.

❑ A well-developed ecotone contains some organisms which are entirely different from that of the adjoining communities.

❑ Ecotones can form between terrestrial and aquatic ecosystems (e.g., wetlands, riparian zones), between different vegetation types (e.g., forest and grassland), or between different successional stages within the same ecosystem (e.g., edge habitats between mature forest and open field).

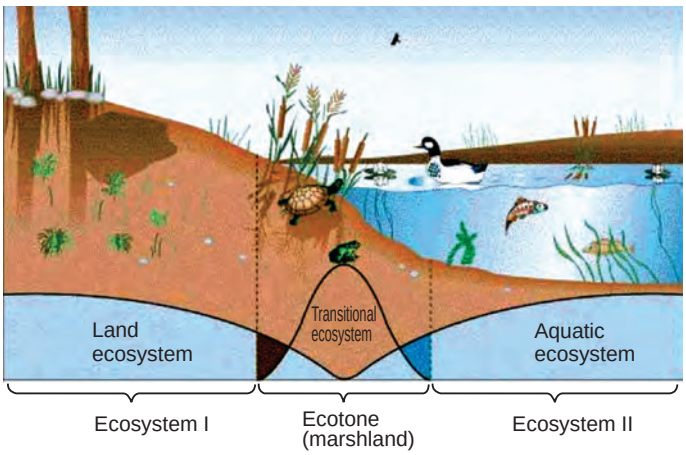


Fig 1.6: An Ecotone

- **Examples of ecotones include:**
  - **Mangrove forests:** Transition zones between marine and terrestrial ecosystems, represent an ecotone.
  - **Wetland Margins:** Transition zones between terrestrial uplands and aquatic habitats such as lakes, rivers, or marshes, where vegetation and soil characteristics change gradually from dry to wet conditions.
  - **Forest-Grassland Boundaries:** Areas where forests transition into grasslands or savannas, often characterized by a mix of tree species from the forest and grasses from the grassland, as well as unique species adapted to the intermediate conditions.
- **Significance**
  - Ecotones are biodiversity **hotspots** between ecosystems, of high environmental and scientific importance.
  - These regions promote **gene flow** between communities, leading to interesting variations and holding evolutionary significance for researchers.
  - **Mobile animals** benefit from ecotones by accessing multiple habitats within a short distance.
  - Ecotones provide **nesting spots** for animals seeking a place to lay their eggs or find nourishment.
  - Ecotones act as **biological buffer states,** safeguarding adjacent ecosystems from potential dangers during catastrophic events.
  - For example, mangrove vegetation absorbs the impact of tsunamis, preventing significant damage to terrestrial regions.

Thus, ecotones play important ecological roles, serving as transition zones for species movement and dispersal, facilitating genetic exchange between adjacent populations, and promoting biodiversity by providing habitat for species adapted to intermediate conditions.

Edge Effect

The edge effect refers to the changes in populations, communities, and ecological processes that occur at the boundary between two different ecosystems. When two ecosystems meet, such as a forest and grassland or a forest and urban area, the transition zone or ecotone experiences distinct environmental conditions compared to the interior of each habitat.

- These conditions result from the interactions between the adjacent habitats and can profoundly influence biodiversity, species distribution, and ecosystem processes.
  - **For example,** the edge habitat may receive more sunlight, experience higher temperatures, and be more susceptible to wind and human disturbances than the interior habitat.
- These environmental changes can affect the abundance and distribution of plant and animal species, leading to shifts in community dynamics and ecological interactions.
- Edge effects can have both positive and negative impacts on biodiversity and ecosystem functioning.
  - On one hand, edge habitats may provide opportunities for species adapted to edge conditions, leading to increased species diversity and ecological resilience.
  - However, edge effects can also pose challenges for species that require intact interior habitats, potentially leading to habitat fragmentation, reduced biodiversity, and altered ecosystem processes.
- The organisms which occur primarily or most abundantly in this zone are known as **edge species.** In terrestrial ecosystems, the edge effect is particularly notable among birds. For instance, bird density is higher in the transitional habitat between forest and desert known as the ecotone.
- **Edge Habitats:** The interface between two distinct habitats, such as the edge of a forest where it meets an open field or agricultural land. Edge habitats can support species that thrive in both environments and may exhibit unique ecological dynamics, such as increased predation pressure or altered microclimatic conditions.

Function of Ecosystem

The ecosystem's function is expansive and encompasses a dynamic system that can be explored through the following three aspects

- Energy Flow
- Biogeochemical cycles (Nutrient Cycling)
- Ecological Succession

ENERGY FLOW

- Energy flow in ecosystems involves the movement of energy among organisms, vital for ecological balance. Primary producers, like plants, algae, and certain bacteria, capture solar energy via photosynthesis, converting it into chemical energy.
- This energy then transfers to consumers across trophic levels, organized by their feeding roles. Herbivores consume producers, while carnivores feed on herbivores, forming a chain of energy transfer. Each trophic level signifies a step in this process, highlighting the interconnectedness of organisms and the reliance on primary production for sustaining life.
- In addition to energy flow through living organisms, energy is also transferred through decomposers and detritivores. Decomposers, such as bacteria and fungi, break down organic matter (dead plants and animals) into simpler compounds, releasing energy in the process. Detritivores, such as earthworms and insects, consume organic detritus and play a crucial role in breaking down organic matter further.

The Lindeman's 10 Percent Law

- Lindeman's 10 percent law, proposed by ecologist Raymond Lindeman, states that only about 10 percent of the energy available at one trophic level is transferred to the next trophic level in an ecosystem.
- This law highlights the inefficiency of energy transfer between trophic levels, with the majority of energy being lost as heat during metabolic processes, such as respiration.
- Consequently, each successive trophic level has less energy available to support organisms, resulting in a pyramid-shaped energy distribution known as an ecological pyramid.
- Lindeman's law emphasizes the importance of primary producers, which capture solar energy and convert it into chemical energy through photosynthesis, as they form the basis of energy flow in ecosystems.

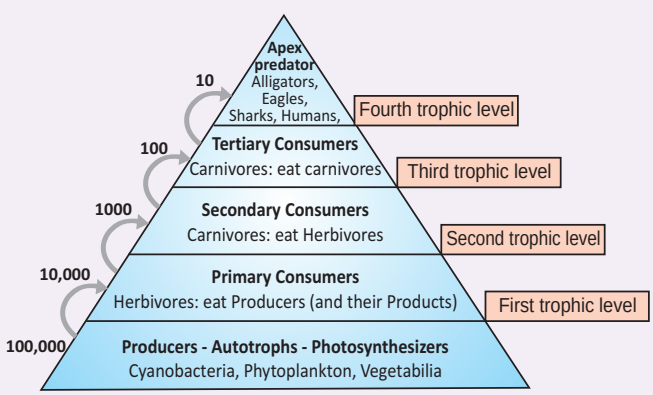


Fig. 1.7: Lindeman's Law of Ten Percent

- However, not all of the energy is transferred, some energy is lost as heat during metabolism, respiration, and other physiological processes. This loss of energy limits the efficiency of energy transfer between trophic levels.

IGNITE YOUR MIND

Unveiling the Invisible Threads: Energy Flow and Trophic Connections

Beyond the visible food chain, what hidden pathways does energy flow through in an ecosystem? Explore the intricate web of trophic interactions and how they sustain the delicate balance of life.

- **Heat Loss and Energy Pyramids:** At each trophic level, a portion of the energy consumed is used by organisms for metabolism, growth, and reproduction, while the rest is lost as heat.
  - As a result, energy pyramids, also known as ecological pyramids, depict the decreasing amount of energy available at higher trophic levels.
  - The base of the pyramid represents primary producers, with subsequent levels representing primary consumers, secondary consumers, and so on.
  - The pyramid narrows at the top, reflecting the decreasing energy available at higher trophic levels. Thus the **pyramid of energy is always upright.**
- Energy flow is essential for maintaining the balance and stability of ecosystems. It supports the growth and reproduction of organisms, regulates population dynamics, and influences nutrient cycling processes. Changes in energy flow, such as disruptions to primary production or alterations in trophic interactions, can have cascading effects on ecosystem structure and function, potentially leading to imbalances and ecological disturbances.

The energy flow in an ecosystem is a dynamic process that involves the capture, transfer, and utilization of energy by organisms at different trophic levels. It is a fundamental aspect of ecosystem function, influencing the structure, diversity, and stability of ecological communities.

Trophic Level

In an ecosystem, a trophic level refers to a position occupied by a group of organisms in a food chain or food web based on their feeding relationships and energy transfer. Each trophic level represents a stage in the transfer of energy and nutrients through the ecosystem, with energy typically flowing from lower to higher trophic levels. Trophic level interaction deals with how the members of an ecosystem are connected based on nutritional needs.

- **Producers (Trophic Level 1):**
  - Producers, also known as **autotrophs,** form the base of the food chain by **converting inorganic substances into organic compounds** using energy from sunlight or inorganic chemical reactions.
  - In terrestrial ecosystems, producers are mainly green plants that undergo photosynthesis, while in aquatic ecosystems, they include phytoplankton, algae, and aquatic plants.
  - Producers synthesize carbohydrates, which serve as the primary source of energy for all other organisms in the ecosystem.

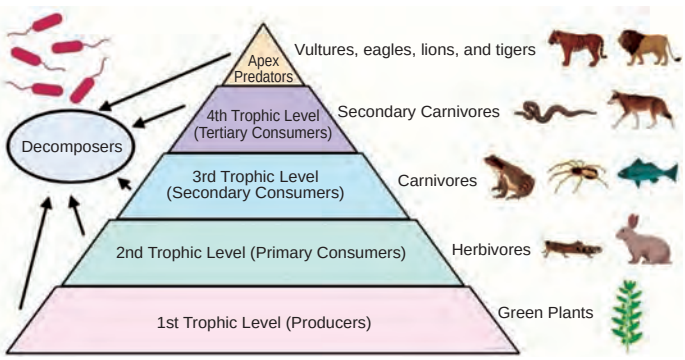


Fig. 1.8: The Trophic Levels

- **Primary Consumers (Trophic Level 2):**
  - Primary consumers, also known as **herbivores,** are organisms that feed directly on producers.
  - They obtain energy and nutrients by consuming plant material or algae.
  - Examples of primary consumers include insects, rabbits, deer, and grazing animals like cows and sheep.
- **Secondary Consumers (Trophic Level 3):**
  - Secondary consumers are organisms that feed on primary consumers.
  - They obtain energy by consuming herbivores or other primary consumers.
  - Examples of secondary consumers include carnivorous animals like snakes, frogs, birds of prey, and small mammals like foxes and coyotes.
- **Tertiary Consumers (Trophic Level 4):**
  - Tertiary consumers are organisms that feed on secondary consumers.
  - They obtain energy by consuming other carnivores or omnivores.
  - Examples of tertiary consumers include top predators such as large carnivores like lions, tigers, wolves, and apex predators like sharks in aquatic ecosystems.
- **Quaternary Consumers and Beyond:**
  - In some ecosystems, there may be additional trophic levels beyond tertiary consumers, including quaternary consumers and higher-order predators.
  - These organisms represent the top of the food chain and play a crucial role in regulating the populations of other species within the ecosystem.
  - Quaternary consumers **(Top Carnivores)** may include predators that feed on tertiary consumers, and the trophic levels continue until energy dissipates or is recycled through decomposers.

Trophic levels thus illustrate the flow of energy and nutrients through an ecosystem, with each level representing a transfer of energy from one set of organisms to another. This energy flow is essential for maintaining ecosystem stability and functioning, as it regulates population dynamics, nutrient cycling, and overall ecosystem health.

The trophic level interaction involves three concepts namely:

- Food Chain
- Food Web
- Ecological Pyramids

Food Chain

- A food chain is a linear sequence of organisms in an ecosystem, depicting the flow of energy and nutrients from one organism to another through consumption.
- It represents a simplified model of the feeding relationships within an ecosystem, illustrating how energy is transferred from producers to consumers and eventually to decomposers.
- Food chains demonstrate the transfer of energy and nutrients from one trophic level to another, with each level representing a step in the flow of energy through the ecosystem. They illustrate the interconnectedness of organisms within ecosystems and the dependence of higher trophic levels on lower ones for energy and sustenance.

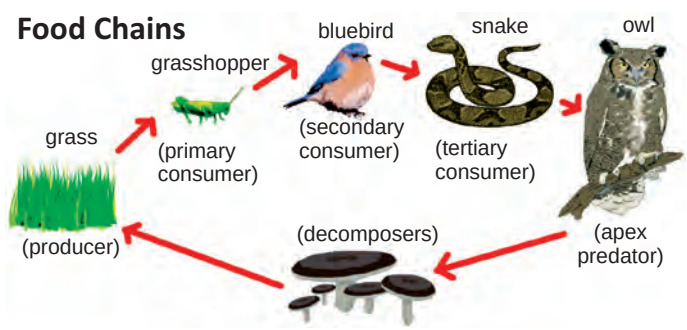


Fig. 1.9: Food Chain

Types of Food Chain

There are various types of food chains, including grazing, aquatic, detritus, parasitic food chains etc, each depicting different pathways of energy flow within ecosystems.

1. Grazing Food Chain

A grazing food chain is a type of food chain that begins with green plants as primary producers and involves herbivores that consume these plants as primary consumers.

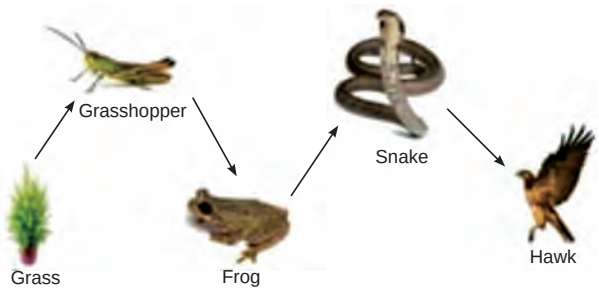


Fig. 1.10: Grazing Food Chain

- The grazing food chain begins with primary producers, green plants, which use photosynthesis to convert sunlight, water, and carbon dioxide into organic compounds. These plants serve as the primary energy source for the ecosystem.
- Herbivores, the primary consumers, consume plant material for energy and nutrients. Secondary consumers, such as carnivores and omnivores, feed on herbivores, transferring energy up the chain. This energy flow continues through tertiary consumers and higher-order predators.
- Each trophic level represents a transfer of energy, highlighting the interconnectedness of organisms in the ecosystem and the dependence on primary producers for sustaining life.

Example of Grazing Food Chain:

- Grasslands provide a classic example of a grazing food chain.
- Primary producers in grasslands include grasses and other herbaceous plants.
- Herbivores such as deer, rabbits, grasshoppers, and cattle feed on these plants.
- Carnivores like wolves, foxes, and birds of prey may then prey on these herbivores.
- The energy flows sequentially from plants to herbivores to carnivores, illustrating the grazing food chain dynamics.

Overall, the grazing food chain represents one of the fundamental pathways of energy flow and nutrient cycling in ecosystems, demonstrating the interconnectedness of organisms and their dependence on primary producers for energy.

2. Aquatic Food Chain

An aquatic food chain refers to the sequence of organisms in an aquatic ecosystem where energy and nutrients are transferred from one organism to another through feeding interactions. These ecosystems can include freshwater habitats like rivers, lakes, and ponds, as well as marine environments such as oceans, seas, and estuaries.

- **Primary Producers:**
  - Primary producers, primarily phytoplankton, algae (Cyanobacteria, Diatoms), and aquatic plants, form the base of the aquatic food chain.
  - Phytoplankton are microscopic algae suspended in water, while aquatic plants are rooted in the substrate of freshwater habitats or attached to surfaces in marine environments.
  - These autotrophic organisms utilize sunlight, water, and nutrients (e.g., carbon dioxide, nitrogen, phosphorus) to perform photosynthesis and produce organic compounds, such as carbohydrates, which store energy.
- **Primary Consumers:**
  - In freshwater ecosystems, primary consumers may include zooplankton, small crustaceans (e.g., daphnia), insect larvae, and herbivorous fish (e.g., minnows, carp).
  - In marine ecosystems, primary consumers can range from zooplankton (e.g., copepods, krill) to herbivorous fish (e.g., damselfish, surgeonfish) and invertebrates (e.g., sea urchins, snails).
- **Secondary Consumers:**
  - In freshwater ecosystems, secondary consumers may include predatory fish (e.g., bass, pike), carnivorous insects (e.g., dragonfly nymphs), and amphibians (e.g., frogs, salamanders).
  - In marine ecosystems, secondary consumers can range from predatory fish (e.g., tuna, sharks) to cephalopods (e.g., squid, octopus) and marine mammals (e.g., seals, dolphins).
- **Tertiary Consumers:**
  - Tertiary consumers occupy the highest trophic level in the aquatic food chain and feed on secondary consumers or other tertiary consumers.
  - In freshwater ecosystems, tertiary consumers may include large predatory fish (e.g., muskellunge, catfish), birds of prey (e.g., herons, eagles), and carnivorous mammals (e.g., otters, mink).
  - In marine ecosystems, tertiary consumers can range from apex predators like orcas and large sharks to marine birds such as pelicans and gulls that feed on fish.

Overall, the aquatic food chain illustrates the interconnectedness of organisms in freshwater and marine habitats, highlighting the flow of energy and nutrients through various trophic levels and the diverse feeding relationships that sustain aquatic ecosystems.

3. Detritus Food Chain

The detritus food chain, also known as the decomposer food chain, is a type of food chain that begins with dead organic matter, such as leaf litter, fallen branches, dead animals, or fecal matter.

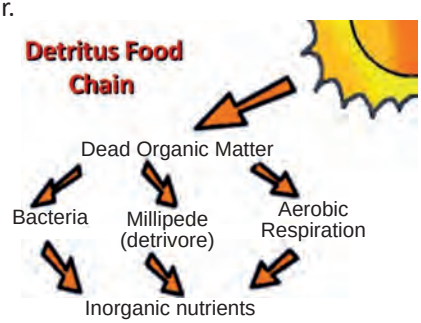


Fig.1.11: Detritus Food Chain

❑ **Detritus (Dead Organic Matter):**

- The detritus food chain starts with detritus, which consists of dead organic material derived from living organisms.
- Dead organic matter can include plant debris like fallen leaves, twigs, and dead animals, as well as organic waste material like feces.
- Detritus serves as a substrate for decomposer organisms that break down complex organic compounds into simpler substances.

❑ **Decomposers:**

- Decomposers are organisms such as bacteria, fungi, and detritivores (organisms that consume detritus) that play a crucial role in breaking down dead organic matter.
- Decomposers secrete enzymes that break down complex organic molecules into simpler compounds, such as carbon dioxide, water, and mineral nutrients.
- Bacteria and fungi are particularly important decomposers in terrestrial ecosystems, while detritivores like earthworms, millipedes, and certain insect larvae contribute to decomposition in both terrestrial and aquatic ecosystems.

❑ **Energy Transfer and Nutrient Cycling:**

- Decomposers facilitate the breakdown of dead organic matter, releasing nutrients like nitrogen, phosphorus, and carbon back into the ecosystem.
- These nutrients are then recycled and made available to primary producers, such as plants, algae, and bacteria, through processes like mineralization and immobilization.
- Primary producers assimilate these nutrients and incorporate them into their tissues, continuing the flow of energy and nutrients through the ecosystem.

❑ **Importance of Detritus Food Chain:**

- The detritus food chain is essential for ecosystem functioning and nutrient cycling, as it recycles organic matter and nutrients back into the environment.
- Decomposers play a vital role in maintaining soil fertility, breaking down dead organic material to release nutrients that support plant growth.
- Detritus-based ecosystems, such as soil and leaf litter communities, support a diverse array of decomposer organisms and contribute to overall ecosystem productivity and stability.

❑ **Example of Detritus Food Chain:**

- In a forest ecosystem, fallen leaves and woody debris provide a substrate for decomposer organisms like fungi and bacteria.
- These decomposers break down the dead organic matter, releasing nutrients that are taken up by plant roots and incorporated into new plant growth.
- Detritivores like earthworms and insect larvae further contribute to decomposition by feeding on the decaying organic material, accelerating the breakdown process.

Overall, the detritus food chain plays a critical role in ecosystem dynamics by recycling nutrients, decomposing organic matter, and supporting primary production, thereby sustaining the health and functioning of ecosystems.

Distinction Between Grazing and Detritus Food Chain

Aspect	Grazing Food Chain	Detritus Food Chain
Primary Energy Source	Living producers (plants)	Decomposing organic matter (detritus)
Initial Organism	Herbivores (consume living producers)	Decomposers (break down dead organic matter)
Intermediate Consumers	Carnivores (consume herbivores)	Detritivores (consume detritus)
Energy Flow	Direct consumption pathway	Indirect consumption pathway through decay
Example	Grass → Grasshopper → Frog → Snake	Fallen leaves → Earthworms → Birds

4. The Parasitic Food Chain

The parasitic food chain is a type of food chain where energy and nutrients flow from a host organism to a parasite, which exploits the host for its own benefit. Here's an explanation of the parasitic food chain:

❑ **Host Organism:**

- The parasitic food chain begins with a host organism, which serves as the primary energy source and habitat for the parasite.
- The host organism can be any living organism, including plants, animals, or even microorganisms, depending on the type of parasite involved.
- Parasites have evolved various adaptations to exploit their hosts, including specialized structures for attachment, feeding, and reproduction.

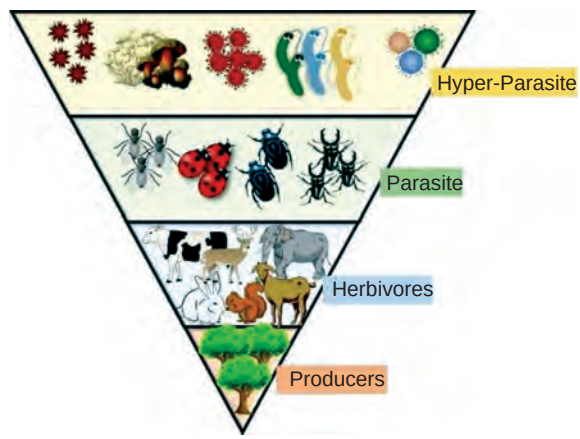


Fig. 1.12: Parasitic Food Chain

❑ **Energy Transfer and Nutrient Cycling:**

- In a parasitic food chain, energy and nutrients flow from the host organism to the parasite through various interactions, including feeding, attachment, and reproduction.
- Parasites extract energy and nutrients from the host's body fluids, tissues, or cells, often causing harm or damage to the host in the process.
- Some parasites may manipulate the behavior or physiology of the host to enhance their own survival and reproductive success, further affecting the dynamics of the parasitic food chain.

❑ **Impacts on Host:**

- Parasites can have various effects on their host organisms, ranging from mild irritation to severe disease and even death.
- Chronic parasitic infections can weaken the host's immune system, reduce its reproductive fitness, and impair its ability to forage, evade predators, or compete for resources.
- In some cases, parasites may serve as vectors for transmitting infectious diseases between hosts, amplifying the spread of pathogens within populations or ecosystems.

❑ **Examples of Parasitic Food Chains:**

- Malaria parasites (Plasmodium spp.) are transmitted to humans through the bite of infected mosquitoes (Anopheles spp.), with the parasite reproducing and developing within the human host's bloodstream, causing symptoms of malaria.
- Another example is the relationship between tapeworms (parasites) and their vertebrate hosts, where tapeworm larvae infect the host's digestive tract and mature into adult worms, feeding on nutrients absorbed by the host from its diet.

❑ **Parasite:**

- The parasite is an organism that derives its energy and nutrients from a living host organism, often at the host's expense.
- Parasites can be classified into different categories based on their relationship with the host, such as ectoparasites (external parasites) and endoparasites (internal parasites).
- Ectoparasites, like ticks, lice, and fleas, live on the surface of the host's body and feed on its blood or tissues.
- Endoparasites, such as certain worms and protozoa, live inside the host's body and feed on its internal organs or tissues.

Overall, the parasitic food chain represents a specialized form of energy flow within ecosystems, where parasites play a crucial role in regulating host populations, influencing community structure, and shaping ecosystem dynamics.

Food Web

❑ A food web refers to the **complex network of feeding relationships** among various organisms in an ecosystem, depicting multiple interconnected food chains.

❑ Unlike a linear food chain that shows a single pathway of energy flow from one organism to another, a food web illustrates the intricate and overlapping interactions between producers, consumers, and decomposers within an ecosystem.

❑ It provides a more comprehensive understanding of energy transfer and nutrient cycling by showcasing the diversity of species and the multitude of feeding connections present in a given habitat.

❑ If any of the intermediate food chains are removed, the succeeding links of the chain will be affected largely.

❑ In a food web, each organism occupies a specific trophic level based on its position in the feeding hierarchy. Producers, such as plants and algae, form the base of the food web by converting sunlight into chemical energy through photosynthesis. Primary consumers, or herbivores, feed directly on producers, while secondary consumers consume primary consumers. Tertiary consumers may prey on secondary consumers, and so on, creating a chain of energy transfer through different trophic levels.

❑ Additionally, food webs incorporate decomposers and detritivores, which play a vital role in recycling nutrients by decomposing organic matter and returning essential elements to the environment. This interconnected web of feeding relationships allows for energy to flow and nutrients to cycle efficiently within an ecosystem, contributing to its stability and functioning.

Overall, food webs provide a holistic view of the complex interactions and dependencies among organisms in an ecosystem, emphasizing the interconnectedness and interdependence of life forms within a given habitat.

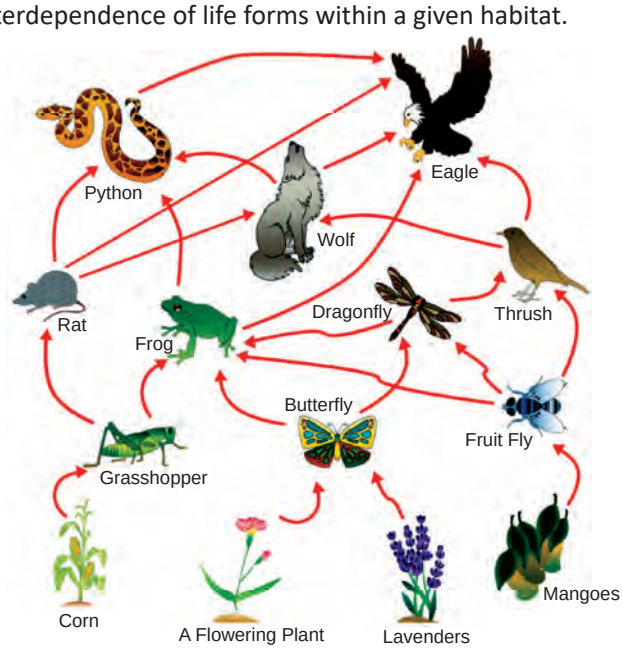


Fig. 1.13: Food Web

Ecological Pyramid

An ecological pyramid, also known as a trophic pyramid, is a graphical representation of the trophic structure and energy flow within an ecosystem. It illustrates the distribution of biomass, energy, or numbers of organisms among different trophic levels within a food chain or food web. **The food producer forms the base of the pyramid and the top carnivore forms the tip. Other trophic levels are in between.**

Ecological pyramids typically consist of horizontal bars or layers stacked on top of each other, arranged sequentially from primary producer level through herbivore, carnivore onwards. Each layer signifies a distinct trophic level, and the length of each bar corresponds to the total population of organisms at each trophic level in an ecosystem.

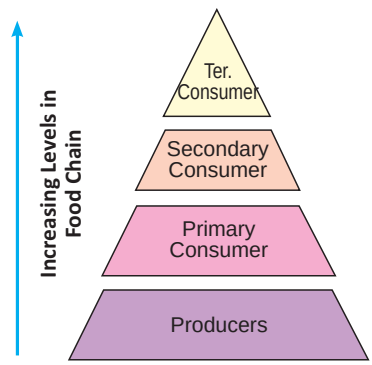


Fig. 1.14: Ecological Pyramid

Levels of pyramids: The different levels of pyramids in ecology, such as energy pyramids or biomass pyramids, represent distinct trophic levels within an ecosystem. Each level signifies a specific position in the food chain or food web, indicating the flow of energy or biomass through the ecosystem. Here's a breakdown of what each level typically represents:

- **Producers:** Found at the base of the pyramid.
- **Primary Consumers:** Located above producers in the pyramid.
- **Secondary Consumers:** Positioned above primary consumers.
- **Tertiary Consumers:** Found at higher levels in the pyramid.

Types of Pyramid

There are three main types of ecological pyramids:

1. Pyramid of Numbers: The pyramid of numbers is a graphical representation of the number of organisms at each trophic level in a food chain or food web.

Its major features include:

- The pyramid typically takes the shape of a pyramid or triangle, with the base representing the primary producers and successive layers representing the consumers at higher trophic levels.
- Each layer of the pyramid represents the number of organisms present at a particular trophic level. The width of each layer corresponds to the number of individuals, with wider layers indicating a larger population size.

- **Types of Pyramid of Numbers:**
  - **Upright Pyramid:** The more common type of pyramid, **where the number of organisms decreases from lower to higher trophic level,** resulting in a pyramid with a broad base and narrowing towards the top. This type of pyramid can be seen in the grassland ecosystem.
    - In grassland ecosystems, the pyramid of numbers typically appears upright due to the large population of primary producers (grass) supporting a smaller number of herbivores (grazers), which in turn sustain an even smaller number of carnivores (predators). This upright pyramid reflects the high productivity of grasslands, where abundant vegetation supports a multitude of herbivores, leading to a smaller number of carnivores at the top of the food chain.
  - **Inverted Pyramid:** In some ecosystems, the pyramid of numbers may be inverted, meaning that the number of organisms at higher trophic levels exceeds the number of organisms at lower trophic levels.

    The pyramid of numbers may invert in certain ecosystems due to the presence of a large number of smaller organisms supporting fewer predators or consumers higher up the food chain. This phenomenon occurs in ecosystems with a high reproductive rate among primary producers or herbivores, leading to a broad base of the pyramid, while relatively fewer predators or higher-level consumers exist.
    - This type of pyramid can be seen in parasitic food chain.
    - For example, A forest would have a small number of producers ie. few big trees. Tree (primary producer) being few in number would represent the base of the pyramid and the dependent herbivores (Example- birds) represent the next higher trophic level and it is followed by parasites (lice and bugs) in the next trophic level. Hyper Parasites (bacteria, fungi etc.) being at higher trophic levels represent higher numbers. And the resulting pyramid is in an inverted shape.
  - **Irregular/Spindle-shaped Pyramid:** In certain ecosystems, the pyramid of numbers may not follow a strictly pyramid-shaped pattern due to variations in population sizes, species interactions, or ecological factors.
    - In aquatic ecosystems, particularly in nutrient-rich environments like eutrophic lakes, the pyramid of numbers may be irregular due to the presence of phytoplankton. Phytoplankton, microscopic algae that form the base of the aquatic food web, can reproduce rapidly and exist in vast numbers, outnumbering the primary consumers (zooplankton) that feed on them.

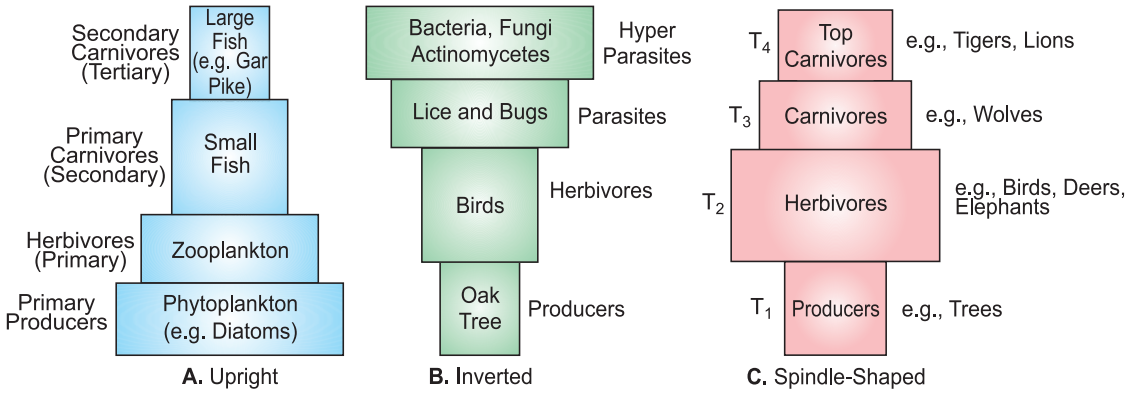


Fig. 1.15: Pyramids of Number: A. In Pond Ecosystem; B. In Parasitic Food Chain; C. Tree Ecosystem.

2. Pyramid of Biomass:

- The pyramid of biomass is a graphical representation that shows the relationship between the biomass (total dry weight of organisms) at different trophic levels within an ecosystem.
- In this method individuals in each trophic level are weighed instead of being counted. This overcomes the size difference problem because all kinds of organisms at a trophic level are weighed. Biomass is measured in g/m3. This results in the formation of a pyramid of biomass.
- The shape of a pyramid of biomass can vary depending on the ecosystem and the relative biomass of organisms at each trophic level. It can be upright, inverted, or even partially upright and partially inverted.
  - **Upright Pyramid:** In most ecosystems, the pyramid of biomass is upright, meaning that the biomass of producers (such as plants) is greater than the biomass of primary consumers (herbivores), which in turn is greater than the biomass of secondary consumers (carnivores), and so on.
    - This is because energy is lost as heat and metabolic processes occur, resulting in a decrease in biomass at higher trophic levels.

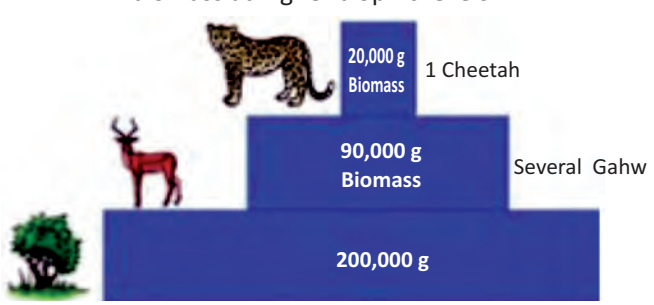


Fig. 1.16: Upright Pyramid of Biomass

  - **Inverted Pyramid:** In some ecosystems, particularly aquatic ecosystems like oceans, the pyramid of biomass can be inverted.
    - This occurs when the biomass of consumers (such as zooplankton) is greater than the biomass of producers (such as phytoplankton). This can happen due to rapid turnover rates of producers or the presence of large consumers with low biomass but high turnover rates.

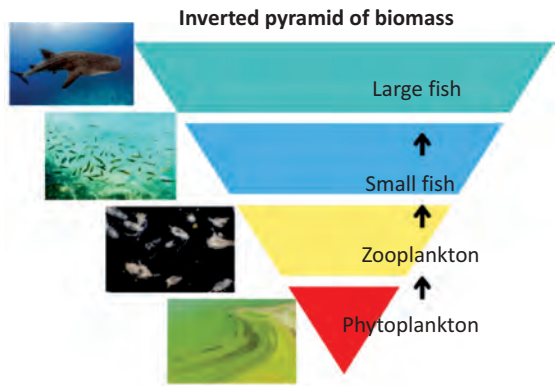


Fig. 1.17: Inverted Pyramid of Biomass

  - **Partially Upright and Inverted:** In certain ecosystems, the pyramid of biomass may exhibit a combination of upright and inverted sections. For example, in a forest ecosystem, the biomass of producers (trees) may be greater than the biomass of primary consumers (herbivores), but the biomass of secondary consumers (predators) may be greater than that of the primary consumers due to factors such as population dynamics and energy transfer efficiency.

3. Pyramid of Energy:

- To compare the functional roles of the trophic levels in an ecosystem, an energy pyramid is most suitable. Pyramid of energy illustrates the flow of energy from producers to consumers. It is based on the concept of the flow of energy in a food chain proposed by Lindemann. Energy pyramids indicate how much energy is required in the next trophic level, hence the pyramid of energy is **always upward.** It indicates the actual role played by various organisms in energy transfer.
- **Unidirectional Flow:** Energy flows through the pyramid from the base (primary producers) to the apex (top consumers) in a unidirectional manner, following the path of energy transfer in the food chain.
- **Decreasing Energy Levels:** Each successive trophic level in the pyramid typically contains less energy than the one below it. This decrease occurs because energy is lost as heat during metabolic processes, such as respiration, and is not all transferred to higher trophic levels.

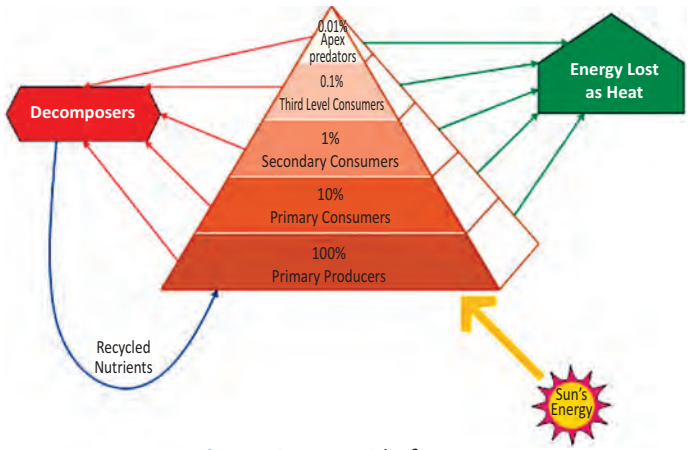


Fig. 1.18: Pyramid of Energy

- **Pyramid Shape:** The pyramid takes on a characteristic shape, with a broad base representing the primary producers (e.g., plants), followed by successively narrower levels representing primary consumers (herbivores), secondary consumers (carnivores), and so on. This shape reflects the decreasing energy available at higher trophic levels.
- **Relative Biomass:** The size of each trophic level in the pyramid is often proportional to the biomass or abundance of organisms at that level. This means that the base of the pyramid, representing primary producers, is typically larger than the higher trophic levels.
- **Trophic Efficiency:** The pyramid of energy illustrates the inefficiency of energy transfer between trophic levels, with only a small fraction of energy being passed on from one level to the next. Trophic efficiency is typically low, around 10 percent, due to energy losses at each step of the food chain.

Importance of Ecological Pyramids

Ecological pyramids serve as graphical representations of trophic levels within ecosystems, depicting the distribution of energy, biomass, or organism numbers. The significance of these pyramids in understanding ecological dynamics is multifaceted:

- **Trophic Interactions:** Ecological pyramids effectively illustrate feeding relationships among organisms across ecosystems, offering insights into diverse dietary patterns.
- **Energy Transfer Efficiency:** An essential role of ecological pyramids is to showcase energy transfer efficiency across trophic levels, providing an understanding of energy flow and associated losses.
- **Monitoring Ecosystem Health:** The structure and distribution of organisms within ecological pyramids can indicate overall ecosystem health and stability, allowing for timely interventions against potential threats.
- **Biodiversity Insights:** Ecological pyramids offer valuable data on regional biodiversity; a diverse and balanced pyramid suggests a healthy ecosystem, while imbalances may indicate threats.
- **Food-Consumer Relationship:** Ecological pyramids are founded on the food-consumer relationship, crucial for understanding organism interdependencies within ecosystems.
- **Maintaining Ecological Equilibrium:** These pyramids play a vital role in ecosystem balance by providing a clear picture of energy distribution, ensuring sustainable flow across trophic levels.
- **Indicator of Environmental Harm:** Disruptions in the food chain can disturb ecological pyramid structure, potentially harming the entire ecosystem.
- **Comprehensive Overview:** Ecological pyramids provide a holistic view of habitats, illustrating nutrition and feeding habits crucial for ecological studies and conservation endeavors.

Constraints of Ecological Pyramids

Ecological pyramids, which graphically portray the distribution of organisms across trophic levels, are insightful tools for understanding ecosystem structure and function. Nevertheless, they are subject to several limitations:

- **Elaborate Food Webs:** Ecological pyramids primarily illustrate straightforward food chains, disregarding the intricate nature of natural food webs where numerous species occupy diverse trophic levels.
- **Omission of Saprophytes:** Despite the pivotal role of saprophytes in recycling nutrients within ecosystems, ecological pyramids often disregard them, categorizing them as non-living components.
- **Ignoring Seasonal and Climatic Factors:** Ecological pyramids overlook seasonal and climatic fluctuations, which significantly influence the distribution and abundance of organisms across trophic levels.
- **Applicability to Simplistic Food Chains:** Designed for straightforward food chains, ecological pyramids may not accurately represent the complexities of actual ecosystems, where multiple species interact within complex food webs.
- **Disregarding Energy Sources:** Essential energy sources like litter and humus, crucial for nutrient cycling and energy flow, are excluded from ecological pyramids.
- **Presence of Same Species at Various Levels:** In some ecosystems, a single species may occupy multiple trophic levels, yet ecological pyramids fail to account for this, potentially resulting in inaccuracies.
- **Absence of Insight into Energy Transfer Rate:** While ecological pyramids demonstrate energy distribution across trophic levels, they do not offer insights into the rate or efficiency of energy transfer between these levels.

In conclusion, while ecological pyramids offer valuable insights into energy flow and trophic structure within ecosystems, their limitations, such as oversimplification and variability across different ecosystems, underscore the need for complementary approaches to fully understand ecological dynamics and inform conservation efforts.

Pollutants of Trophic Level: Bioaccumulation and Biomagnification

Pollutants, especially non-biodegradable ones pass through various trophic levels in an ecosystem. Non-degradable pollutants (persistent pollutants), which cannot be broken down by detritivores, not only migrate through the trophic levels but also stay there for a long time. In addition, some pollutants have a proclivity for accumulating in larger quantities at higher trophic levels. There are two basic processes involved in the movement of these pollutants: Bioaccumulation and Biomagnification.

Biomagnification and bioaccumulation are two related processes that occur within ecosystems, particularly in aquatic environments, and involve the accumulation of substances, typically toxins or pollutants, within organisms.

Bioaccumulation

Bioaccumulation refers to the gradual accumulation of substances, such as pollutants or toxins, in the tissues of living organisms over time.

- This process occurs when organisms absorb substances from their environment through various routes such as ingestion, inhalation, or direct contact with contaminated water, soil, or air. Once absorbed, these substances may be stored in the organism's tissues, where they can persist and accumulate to higher concentrations over time.
- Bioaccumulation is influenced by factors such as the chemical properties of the substance, the organism's physiology, its feeding habits, and the environment's concentration of the substance.
- Organisms at lower trophic levels may accumulate contaminants from their food sources, and these contaminants can become more concentrated as they move up the food chain through a process called biomagnification.

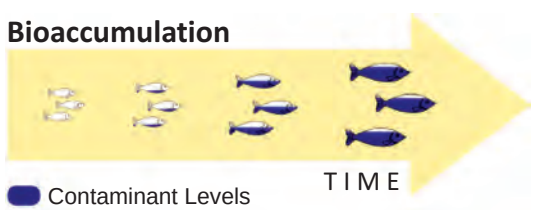


Fig. 1.19: Bioaccumulation

- **Example**
  - **DDT in Birds:** DDT, a pesticide widely used in the mid-20th century, accumulates in the fatty tissues of organisms. Birds like the bald eagle and peregrine falcon, which are higher up in the food chain, accumulated dangerous levels of DDT through their prey. This led to thinning of their eggshells and population decline due to reproductive issues.

Biomagnification

Biomagnification refers to the **increasing concentration** of certain substances, such as persistent organic pollutants (POPs) or heavy metals, as they move up the food chain from lower to higher trophic levels.

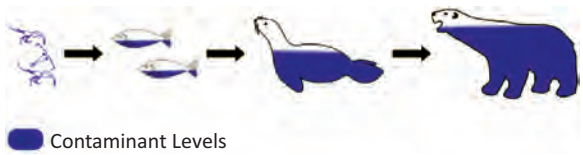


Fig. 1.20: Biomagnification

- In biomagnification, organisms at higher trophic levels accumulate higher concentrations of contaminants compared to those at lower trophic levels.
- This phenomenon occurs because substances that are not easily metabolized or excreted by organisms tend to accumulate in their tissues over time. As predators consume multiple prey organisms, each containing some level of contaminants, the contaminants become more concentrated in the predator's body.
- Biomagnification is particularly prominent in aquatic ecosystems, where lipophilic (fat-soluble) substances can accumulate in the fatty tissues of organisms and become increasingly concentrated as they move up the food chain.
- At the top of the food chain, organisms such as predatory fish, marine mammals, and humans may experience the highest levels of biomagnification, posing potential health risks due to exposure to high concentrations of contaminants.
- **Example:**
  - **PCBs in Great Lakes Fish:** Polychlorinated biphenyls (PCBs), once used in electrical equipment and other industrial applications, persist in the environment. In the Great Lakes region, PCBs have biomagnified in the aquatic food chain. Small organisms absorb PCBs, which then accumulate in larger fish such as lake trout and salmon. This poses health risks to both wildlife and humans consuming contaminated fish.

Both bioaccumulation and biomagnification have significant implications for ecosystem health, biodiversity, and human health. They can lead to ecological disruptions, reproductive impairments, developmental abnormalities, and adverse health effects in wildlife and humans exposed to contaminated food sources. Therefore, understanding and mitigating these processes are essential for environmental management and pollution control efforts.

Types of Interaction Between Species

The interaction between species within an ecosystem plays a fundamental role in shaping the dynamics and functioning of natural communities. These interactions can take various forms, ranging from mutually beneficial relationships to competitive struggles for limited resources.

- Understanding these interactions is crucial for comprehending the intricate web of life and its complexities which further helps ecologists and environmental scientists striving to conserve biodiversity and maintain the stability of natural communities.
- Species interactions can be categorized into several types, each with its own unique characteristics and ecological significance.
- In the table below, we explore the major types of species interactions along with examples illustrating each type. This table provides insights into the diverse ways in which organisms interact with one another in nature, highlighting the interconnectedness and interdependence of life within ecosystems.

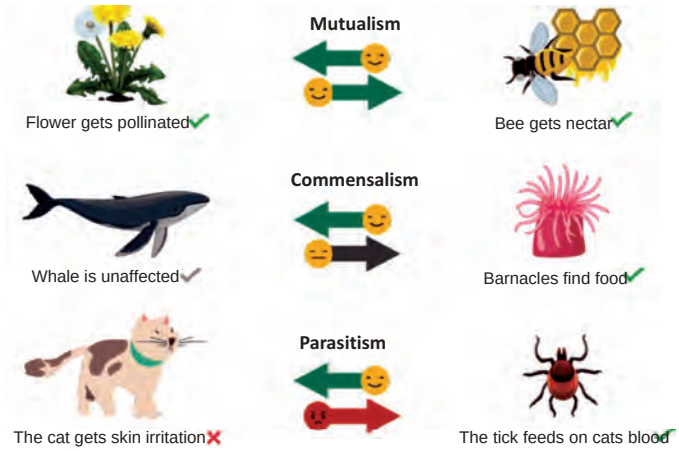


Fig. 1.21: Types of Interaction between Species

Type of Interaction	Definition	Example 1	Example 2	Example 3
Mutualism	Both species benefit from the interaction.	Bee pollinating flowers, both get nectar and pollen.	Clownfish and sea anemones, mutual protection.	Lichen (fungus and algae), mutualistic relationship.
Commensalism	One species benefits, the other is unaffected.	Barnacles attaching to whales, barnacles benefit while whales are unaffected.	Epiphytic plants growing on tree branches, plants benefit, tree is unaffected.	Remoras hitching a ride on sharks, remoras get protection and scraps, shark is unaffected.
Parasitism	One species benefits at the expense of the other.	Tick feeding on a dog's blood, tick benefits, dog is harmed.	Tapeworms living in the intestines of animals, tapeworm benefits, host is harmed.	Mosquitoes feeding on human blood, mosquitoes benefit, humans are harmed.
Predation	One species kills and consumes the other.	Lion hunting and eating a zebra.	Snake capturing and eating a mouse.	Eagle preying on fish in a river.
Competition	Both species are negatively affected by sharing limited resources.	Lions and hyenas competing for prey in the savanna.	Plants competing for sunlight and nutrients in a forest.	Birds competing for nesting sites in a tree.
Amensalism	One species is harmed, the other is unaffected.	Black walnut trees releasing toxins that inhibit the growth of nearby plants.	Antibiotic-producing bacteria inhibiting the growth of other bacteria.	Allelopathic plants releasing chemicals that inhibit the growth of nearby plants.
Facilitation	One species indirectly benefits another.	Nurse plants providing shade and shelter for seedlings.	Coral reefs providing habitat for a diverse range of marine species.	Dead trees providing nesting sites for woodpeckers and other cavity-nesting birds.

BIOGEOCHEMICAL CYCLE

The concept of a biogeochemical cycle revolves around the movement and transformation of essential elements and compounds between living organisms, the environment, and geological processes. These cycles involve the circulation of elements such as carbon, nitrogen, phosphorus, sulfur, and water through various reservoirs, including the atmosphere, oceans, soils, and living organisms.

- The term "biogeochemical" highlights the interconnectedness of biological, geological, and chemical processes involved in these cycles.

The biogeochemical cycles are essential for maintaining the balance of elements necessary for life on earth. They regulate the availability of nutrients and energy within ecosystems, influence climate patterns, and impact the composition of the atmosphere and hydrosphere.

There are several key components or parts of a biogeochemical cycle:

- **Reservoirs or Pools:** These are the various places where a particular element or compound is stored. Reservoirs can include the atmosphere, oceans, soil, rocks, living organisms, and fossil fuels. For example, in the carbon cycle, reservoirs include the atmosphere, terrestrial vegetation, soils, oceans, and fossil fuel deposits.

- **Fluxes or Pathways:** Fluxes refer to the movement of elements or compounds between different reservoirs. These fluxes can occur through various processes such as photosynthesis, respiration, decomposition, erosion, weathering, precipitation, and evaporation. In the nitrogen cycle, fluxes include nitrogen fixation, nitrification, denitrification, and ammonification.
- **Exchange Processes:** These processes facilitate the transfer of elements or compounds between different reservoirs. Exchange processes can be biological, chemical, or physical in nature. Examples include the uptake of carbon dioxide by plants during photosynthesis, the release of oxygen during photosynthesis, and the exchange of carbon dioxide between the atmosphere and oceans.
- **Biological Processes:** Living organisms play a crucial role in biogeochemical cycles. They participate in processes such as photosynthesis, respiration, decomposition, nitrogen fixation, and nutrient cycling. For instance, plants take up carbon dioxide from the atmosphere during photosynthesis, incorporating carbon into their tissues. When organisms respire, they release carbon dioxide back into the atmosphere.
- **Geochemical Processes:** Geological processes such as weathering, erosion, sedimentation, and volcanic activity also contribute to biogeochemical cycles. For example, weathering of rocks releases phosphorus into the soil, where it becomes available for uptake by plants.
- **Anthropogenic Influences:** Human activities have significantly altered biogeochemical cycles through activities such as deforestation, agriculture, industrialization, and the burning of fossil fuels. These activities have led to increased concentrations of greenhouse gasses, nutrient pollution, and disruptions to natural cycles.

Types of Biogeochemical Cycle

Biogeochemical cycles can be classified into several types based on the elements involved and the processes that drive them. Here's a brief classification:

- **Gaseous Cycles:** These cycles involve elements that primarily cycle through the atmosphere in gaseous forms. Examples include:
  - **Carbon Cycle:** Involves the cycling of carbon between the atmosphere, biosphere, oceans, and geosphere in the form of carbon dioxide (CO_2) and methane (CH_4).
  - **Nitrogen Cycle:** Involves the cycling of nitrogen between the atmosphere, soil, water bodies, and living organisms in various forms such as nitrogen gas (N_2), ammonia (NH_3), nitrate (NO_3^-), and nitrite (NO_2^-).
  - **Oxygen Cycle:** Involves the cycling of oxygen between the atmosphere, biosphere, and hydrosphere through processes like photosynthesis, respiration, and chemical reactions.
- **Sedimentary Cycles:** These cycles involve elements that primarily cycle through the lithosphere (rocks and sediments) and are characterized by long-term storage in geological formations. Examples include:
  - **Phosphorus Cycle:** Involves the cycling of phosphorus between rocks, soil, water bodies, and living organisms in the form of phosphate ions (PO_4Z^{3-}).
  - **Sulfur Cycle:** Involves the cycling of sulfur between the atmosphere, lithosphere, hydrosphere, and biosphere in various forms such as sulfur dioxide (SO_2), hydrogen sulfide (H_2S), and sulfate (SO_4^{2-}).

Gaseous Cycles

Let us first study some of the most important gaseous cycles, namely- Water, Carbon, Nitrogen and Oxygen

Carbon Cycle

The carbon cycle is a complex biogeochemical process that involves the movement of carbon among various reservoirs or compartments in Earth's atmosphere, biosphere, hydrosphere, and geosphere. It comprises several key components, including reservoirs, flow processes, exchanges, and other important mechanisms:

- **Reservoirs:** Carbon is stored in different reservoirs, or compartments, across Earth's systems. These reservoirs include:
  - **Atmosphere:** Contains carbon dioxide (CO_2) and methane (CH_4), mainly from respiration, combustion, and human activities.
  - **Terrestrial Biosphere:** Stored in plants, soil, and organisms through photosynthesis and respiration.
  - **Oceans:** Contain dissolved inorganic carbon (DIC) and absorb CO_2 from the atmosphere.
  - **Geosphere:** Carbon is stored in rocks, sediments, and fossil fuels within the Earth's crust, released through geological processes.
- **Flow Processes:** Carbon moves between reservoirs through various natural and anthropogenic processes:
  - **Photosynthesis:** Plants, algae, and some bacteria use sunlight to convert CO_2 from the atmosphere into organic carbon compounds during photosynthesis. This process removes carbon from the atmosphere and stores it in plant tissues.
  - **Respiration:** Both plants and animals release CO_2 back into the atmosphere through respiration when they break down organic compounds to obtain energy. This process is the opposite of photosynthesis and contributes to the carbon cycle's dynamic equilibrium.
  - **Decomposition:** Decomposers like bacteria and fungi break down dead organic matter, releasing CO_2 into the soil and atmosphere. Decomposition is essential for recycling nutrients and carbon within ecosystems.

- **Combustion:** Human activities, such as burning fossil fuels for energy and deforestation, release large amounts of carbon stored in fossil fuels into the atmosphere as CO_2. This process significantly alters the natural carbon cycle and contributes to climate change.

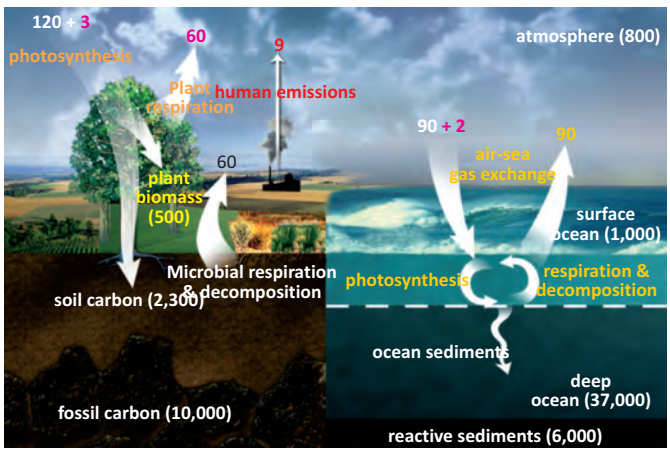


Fig. 1.22: The Carbon Cycle

- **Weathering:** Physical and chemical weathering of rocks on Earth's surface can release carbon stored in minerals like calcium carbonate (limestone). This carbon enters soil and water systems, where it can be further transported and transformed.
- **Burial and Sedimentation:** Dead organic matter can be buried in sediments over long periods, sequestering carbon from the atmosphere and forming fossil fuels like coal, oil, and natural gas.
- **Volcanic Activity:** Volcanic eruptions release carbon dioxide and other gases stored within Earth's interior into the atmosphere. While volcanic activity is a natural part of the carbon cycle, it can contribute to short-term fluctuations in atmospheric CO_2 levels.

❑ **Exchanges:** Carbon exchanges occur between different reservoirs through various pathways:

- **Atmosphere-Biosphere Exchange:** Carbon dioxide is exchanged between the atmosphere and terrestrial vegetation through photosynthesis and respiration. Plants absorb CO_2 during photosynthesis, converting it into organic carbon, while respiration releases CO_2 back into the atmosphere.
- **Atmosphere-Ocean Exchange:** CO_2 dissolves in seawater, where it can be taken up by marine organisms like phytoplankton and corals during photosynthesis. This process, known as the biological pump, transfers carbon from the atmosphere to the oceans. Conversely, CO_2 can be released back into the atmosphere through oceanic outgassing.
- **Biosphere-Geosphere Exchange:** Carbon is transferred between living organisms and soil through decomposition, nutrient cycling, and the formation of organic matter. Dead organic matter can become buried in sediments, contributing to long-term carbon storage in the geosphere.
- **Geosphere-Atmosphere Exchange:** Carbon stored in rocks and minerals can be released into the atmosphere through volcanic eruptions, weathering, and erosion. Conversely, atmospheric CO_2 can be absorbed by rocks through processes like carbonation and mineralization.

❑ **Other Important Components:**

- **Carbon Sinks:** These are reservoirs that absorb more carbon than they release, helping to mitigate the buildup of CO_2 in the atmosphere. Carbon sinks include forests, oceans, and soil, which sequester carbon through photosynthesis, sedimentation, and burial.
- **Carbon Sources:** These are reservoirs that release more carbon than they absorb, contributing to the accumulation of CO_2 in the atmosphere. Human activities like fossil fuel combustion, deforestation, and land-use changes are significant carbon sources.
- **Feedback Mechanisms:** Changes in carbon cycling can have feedback effects on Earth's climate system, influencing factors like temperature, precipitation patterns, and ocean acidity. For example, increased CO_2 levels can lead to warmer temperatures, which may accelerate processes like permafrost thawing and forest degradation, releasing more carbon into the atmosphere and exacerbating climate change.

By studying how carbon moves through Earth's systems, scientists can better predict and mitigate the impacts of human activities on the global carbon cycle and its associated consequences for the planet.

Nitrogen Cycle

The nitrogen cycle is a vital biogeochemical process that governs the movement and transformation of nitrogen across Earth's ecosystems. Nitrogen, an essential element for all living organisms, exists in various forms and undergoes intricate cycling between the atmosphere, soil, water bodies, and living organisms. Understanding the nitrogen cycle is crucial for comprehending ecosystem dynamics, nutrient cycling, and the impacts of human activities on environmental health.

❑ **Reservoirs:** Nitrogen is a crucial element found in various forms across Earth's systems. The primary reservoirs of nitrogen include:

- **Atmosphere:** Comprises 78% nitrogen gas (N_2), inert until converted into ammonia or nitrate.
- **Soil:** Abundant in nitrogen compounds vital for plant growth and microbial processes.
- **Living Organisms:** Essential for proteins, nucleic acids; acquired from soil.
- **Oceans:** Present as dissolved organic and inorganic nitrogen; utilized by marine organisms.
- **Atmospheric Deposition:** Nitrogen compounds deposited via rainfall; enrich terrestrial and aquatic ecosystems.

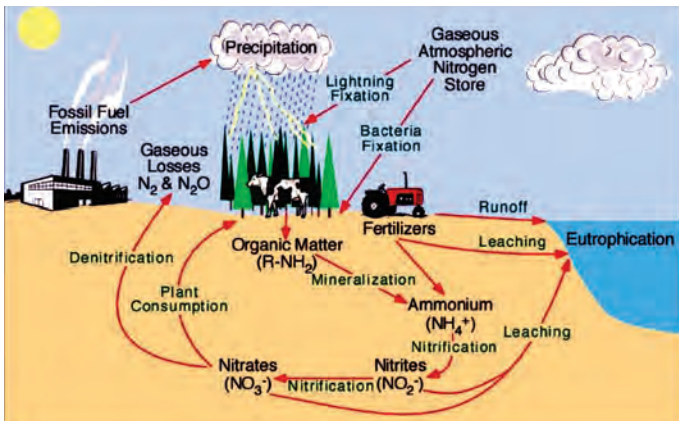


Fig. 1.23: The Nitrogen Cycle

- **Flow Processes:** Nitrogen moves between reservoirs through various biological, physical, and chemical processes:
  - **Nitrogen Fixation:** Nitrogen gas (N_2) in the atmosphere is converted into ammonia (NH_3) or ammonium ions (NH_4^+) by nitrogen-fixing bacteria, which possess the enzyme nitrogenase. This process, known as nitrogen fixation, allows atmospheric nitrogen to become available for biological use and is primarily carried out by symbiotic bacteria in root nodules of leguminous plants and free-living bacteria in soil and aquatic environments.
  - **Nitrification:** Ammonium ions (NH_4^+) produced by nitrogen fixation or released from organic matter are converted into nitrate ions (NO_3^-) through two sequential oxidation reactions carried out by nitrifying bacteria. Ammonium is first oxidized to nitrite (NO_2^-) by ammonium-oxidizing bacteria, then further oxidized to nitrate by nitrite-oxidizing bacteria. Nitrification occurs predominantly in aerobic soil and aquatic environments.
  - **Assimilation:** Plants and other organisms take up nitrate (NO_3^-) and ammonium (NH_4^+) from the soil or water and incorporate nitrogen into organic molecules like proteins, nucleic acids, and chlorophyll.
  - **Ammonification:** Ammonification is the process by which organic nitrogen compounds, such as proteins and nucleic acids from dead plant and animal matter, are converted into ammonium ions (NH_4^+) by decomposer organisms like bacteria and fungi. Ammonification releases nitrogen from organic matter, making it available for reuse by plants and other organisms.
  - **Denitrification:** Denitrification is the microbial process by which nitrate (NO_3^-) is reduced to nitrogen gas (N_2) or other gaseous nitrogen compounds like nitrous oxide (N_2O) by denitrifying bacteria under anaerobic conditions. Denitrification returns nitrogen to the atmosphere, completing the nitrogen cycle and balancing nitrogen inputs and outputs in ecosystems.
- **Exchanges:** Nitrogen exchanges occur between different reservoirs through various pathways:
  - **Soil-Plant Exchange:** Plants acquire nitrogen from the soil in the form of nitrate (NO_3^-) or ammonium (NH_4^+) ions through their roots. Nitrogen is assimilated into organic compounds within plant tissues and used for growth and development. Excess nitrogen may be stored in plant tissues or released back into the soil upon decomposition. Some of the Nitrogen-fixing plants are Alfalfa, Chickpea, Clover, Acacia, Alder, etc.
  - **Plant-Animal Exchange:** Animals obtain nitrogen by consuming plants or other organisms. Nitrogen is assimilated into animal tissues through digestion and metabolic processes. When animals excrete waste products like urine and feces, nitrogen is returned to the soil in the form of organic matter or ammonium ions, contributing to nutrient cycling.
  - **Atmosphere-Soil Exchange:** Atmospheric nitrogen deposition contributes to nitrogen inputs in terrestrial ecosystems, where it can be taken up by plants or microorganisms. Nitrogen-fixing bacteria in soil and root nodules further contribute to nitrogen inputs by converting atmospheric nitrogen into ammonia or nitrate ions, which are available for plant uptake.
  - **Aquatic Exchange:** Nitrogen cycles through aquatic ecosystems via processes like nitrogen fixation, nitrification, and denitrification. Phytoplankton and aquatic plants assimilate nitrogen from the water in the form of nitrate, ammonium, or organic nitrogen compounds, supporting primary productivity and food webs. Decomposition of organic matter releases nitrogen back into the water column, where it can be reused by aquatic organisms or lost through denitrification.
- **Other Important Components:**
  - **Nitrogen Sinks:** These are reservoirs that absorb more nitrogen than they release, helping to regulate nitrogen availability and cycling in ecosystems. Nitrogen sinks include soil organic matter, microbial biomass, and deep ocean sediments, which store nitrogen over long periods and prevent excessive nitrogen loss from ecosystems.
  - **Nitrogen Sources:** These are reservoirs that release more nitrogen than they absorb, contributing to nitrogen inputs in ecosystems. Human activities like industrial nitrogen fixation, agricultural fertilizer use, and combustion of fossil fuels are significant nitrogen sources, altering natural nitrogen cycles and leading to environmental problems like eutrophication and air pollution.

- **Feedback Mechanisms:** Changes in nitrogen cycling can have feedback effects on ecosystem functioning, biodiversity, and nutrient dynamics. For example, increased nitrogen inputs from fertilizers can stimulate plant growth but may also lead to nutrient imbalances, soil acidification, and loss of biodiversity. Understanding these feedback mechanisms is critical for sustainable nitrogen management and ecosystem conservation.

Studying how nitrogen moves through ecosystems helps us develop strategies for sustainable nitrogen management and conservation practices that minimize environmental impacts and maintain ecosystem health.

Oxygen Cycle

The oxygen cycle is a vital biogeochemical process that governs the distribution and cycling of oxygen (O_2) in Earth's atmosphere, biosphere, hydrosphere, and lithosphere. Oxygen plays a fundamental role in sustaining life, serving as a critical component of respiration, combustion, and various chemical reactions. Understanding the oxygen cycle is essential for comprehending ecosystem dynamics, atmospheric chemistry, and global biogeochemical cycles.

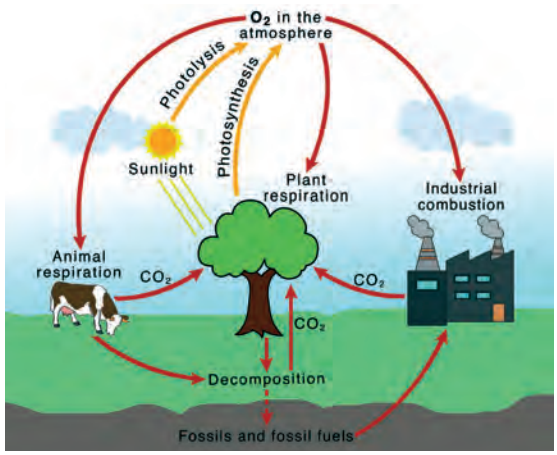


Fig. 1.24: The Oxygen Cycle

❑ Reservoirs of Oxygen:

- **Atmosphere:** Contains 21% oxygen produced by photosynthesis.
- **Biosphere:** Essential for biological molecules; produced by photosynthesis and consumed during respiration.
- **Hydrosphere:** Dissolved in water, supports aquatic life; produced by photosynthesis and consumed during respiration.
- **Lithosphere:** Present in Earth's crust; released and cycled through geological processes.

❑ Flow Processes:

- **Photosynthesis:** Photosynthetic organisms, including plants, algae, and cyanobacteria, utilize sunlight, water, and carbon dioxide to produce oxygen and organic compounds through photosynthesis. During this process, oxygen is released as a byproduct, enriching the atmosphere and supporting aerobic life forms.
- **Respiration:** Living organisms, including plants, animals, and microorganisms, consume oxygen for cellular respiration, a biochemical process that generates energy by oxidizing organic compounds. Oxygen is used as an electron acceptor in the electron transport chain, producing ATP and water as byproducts.
- **Combustion:** Combustion reactions involve the rapid oxidation of organic matter or fossil fuels in the presence of oxygen, releasing energy, heat, and carbon dioxide. Combustion processes like wildfires, industrial activities, and fossil fuel combustion contribute to oxygen consumption and atmospheric pollution.
- **Diffusion and Exchange:** Oxygen exchanges occur between different reservoirs through diffusion, physical mixing, and biological interactions. Oxygen diffuses between the atmosphere and terrestrial or aquatic environments, where it is taken up by organisms or dissolved in water. Oxygen is transported through air-water interfaces, plant stomata, and respiratory surfaces to support metabolic functions and biochemical reactions.

❑ Exchanges:

- **Atmosphere-Biosphere Exchange:** Photosynthetic organisms in the biosphere produce oxygen through photosynthesis, releasing it into the atmosphere as a byproduct. Oxygen is then consumed by aerobic organisms during respiration, completing the atmospheric-oceanic-oxygen cycle.
- **Hydrosphere-Lithosphere Exchange:** Oxygen is exchanged between aquatic environments and the lithosphere through processes like sedimentation, weathering, and biogeochemical reactions. Oxygen-containing compounds in water bodies contribute to chemical weathering, nutrient cycling, and the formation of sedimentary rocks.
- **Human Activities:** Human activities like deforestation, urbanization, and industrialization can alter oxygen cycling and atmospheric oxygen levels. Deforestation reduces oxygen production by removing photosynthetic vegetation, while urbanization and industrial emissions contribute to air pollution and oxygen depletion.

❑ Other Important Components:

- **Oxygen Sinks:** Oxygen sinks are reservoirs that absorb atmospheric oxygen through chemical reactions, biological processes, or physical sequestration. Oxygen sinks include oxidative processes in soils, combustion reactions, and chemical reactions with atmospheric pollutants like nitrogen oxides and volatile organic compounds.

- **Oxygen Sources:** Oxygen sources are reservoirs that release oxygen into the atmosphere through biological or physical processes. Photosynthesis by terrestrial and marine plants, algae, and cyanobacteria is the primary source of atmospheric oxygen, while other sources include atmospheric diffusion, oceanic mixing, and geological outgassing.
- **Feedback Mechanisms:** Changes in oxygen cycling can have feedback effects on ecosystem functioning, climate regulation, and atmospheric chemistry. Oxygen levels influence the distribution and abundance of aerobic organisms, nutrient cycling, and the oxidative capacity of the atmosphere. Understanding these feedback mechanisms is crucial for assessing the impacts of environmental change on oxygen dynamics and ecosystem health.

By studying the oxygen cycle and its interactions with Earth's systems, scientists can better understand the dynamics of atmospheric composition, ecosystem functioning, and global biogeochemical cycles.

Sedimentary Cycle

These cycles involve elements that primarily cycle through the lithosphere (rocks and sediments) and are characterized by long-term storage in geological formations. Phosphorus and Sulphur circulate by means of the sedimentary cycle.

Phosphorus Cycle

The phosphorus cycle is a biogeochemical process that regulates the distribution and cycling of phosphorus (P) in Earth's ecosystems, including terrestrial, aquatic, and soil environments. Phosphorus is an essential nutrient for all living organisms, playing a critical role in cellular structure, energy transfer, and biochemical reactions such as DNA and RNA synthesis. Understanding the phosphorus cycle is crucial for sustaining agricultural productivity, managing nutrient cycling, and mitigating environmental impacts like eutrophication.

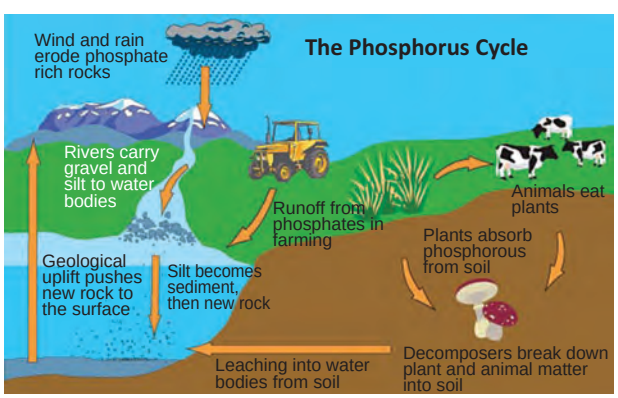

The Phosphorus Cycle
Wind and rain erode phosphate rich rocks
Rivers carry gravel and silt to water bodies
Runoff from phosphates in farming
Animals eat plants
Plants absorb phosphorous from soil
Geological uplift pushes new rock to the surface
Silt becomes sediment, then new rock
Leaching into water bodies from soil
Decomposers break down plant and animal matter into soil

Fig. 1.25: The Phosphorus Cycle

❑ **Reservoirs of Phosphorus:**

- **Soil:** Primarily in minerals, released via weathering and organic matter decomposition, crucial for plant growth.
- **Aquatic Environments:** Cycles between dissolved forms, utilized by aquatic organisms, stored in sediments.
- **Biota:** Incorporated into biomolecules, essential for cellular function.
- **Sedimentary Rocks:** Stored as phosphate minerals, released through geological processes.

❑ **Flow Processes:**

- **Weathering:** Phosphorus is released into the soil through the weathering of phosphorus-rich rocks, minerals, and parent materials. Chemical and physical weathering processes break down phosphate minerals, liberating soluble orthophosphate ions that are available for plant uptake and microbial utilization.
- **Absorption and Uptake:** Plants absorb phosphorus from the soil solution through their root systems, utilizing transport proteins and mycorrhizal associations to facilitate nutrient uptake. Phosphorus is assimilated into plant tissues and incorporated into biomolecules, supporting growth, development, and reproductive processes.
- **Nutrient Cycling:** Phosphorus cycles between biotic and abiotic components of ecosystems through nutrient cycling pathways, including decomposition, mineralization, and microbial transformations. Decomposers break down organic matter, releasing phosphorus into the soil as inorganic phosphate ions that are recycled by plants and microorganisms.
- **Erosion and Sedimentation:** Phosphorus is transported from terrestrial environments to aquatic ecosystems through erosion, runoff, and sedimentation processes. Soil particles, organic matter, and phosphorus-containing sediments are transported by water flow, contributing to nutrient loading, sedimentation, and eutrophication in freshwater and marine habitats.

❑ **Exchanges:**

- **Soil-Plant Exchange:** Phosphorus is exchanged between soil and plants through root uptake, mycorrhizal associations, and soil microbial activity. Plants absorb orthophosphate ions from the soil solution, assimilating phosphorus into their tissues and redistributing it through plant biomass, litterfall, and root exudates.
- **Aquatic Cycling:** Phosphorus cycles between water, sediments, and biota in aquatic environments through processes like uptake, release, and sedimentation. Aquatic organisms assimilate phosphorus from the water column, while sedimentary phosphorus contributes to sedimentary nutrient pools and benthic cycling processes.

- **Human Impacts:** Human activities such as agriculture, urbanization, and industrialization can alter phosphorus cycling and contribute to nutrient pollution in terrestrial and aquatic ecosystems. Excessive fertilizer application, sewage discharge, and runoff from urban areas can lead to eutrophication, algal blooms, and water quality degradation.

❑ **Other Important Components:**

- **Phosphorus Sinks:** Phosphorus sinks are reservoirs that immobilize or sequester phosphorus from the environment through chemical precipitation, adsorption, or biological uptake. Soil minerals, organic matter, and sedimentary rocks serve as long-term sinks for phosphorus, storing it in stable forms that may be inaccessible to organisms.
- **Phosphorus Sources:** Phosphorus sources are reservoirs that release phosphorus into the environment through weathering, erosion, decomposition, and anthropogenic activities. Phosphorus sources include phosphate minerals in rocks, organic matter in soils, wastewater discharge, and agricultural runoff.
- **Feedback Mechanisms:** Changes in phosphorus availability can influence ecosystem dynamics, productivity, and species interactions through feedback mechanisms. Phosphorus limitation may restrict plant growth and primary productivity in terrestrial and aquatic ecosystems, while phosphorus enrichment can lead to eutrophication, algal blooms, and ecological

Sulfur Cycle

The sulfur cycle is a biogeochemical process that governs the distribution and cycling of sulfur (S) in Earth's ecosystems, encompassing terrestrial, aquatic, and atmospheric compartments. Sulfur is an essential element for living organisms, playing crucial roles in amino acids, vitamins, and enzyme cofactors. Understanding the sulfur cycle is vital for managing sulfur-containing pollutants, assessing ecosystem health, and mitigating environmental impacts such as acid rain and climate change.

Sulfur Cycle

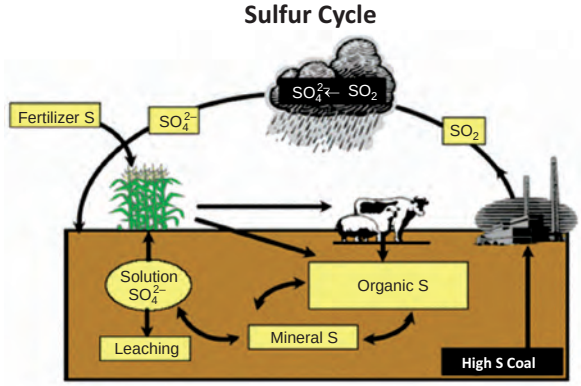


Fig. 1.26: The Sulfur Cycle

❑ **Reservoirs of Sulfur:**

- **Atmosphere:** Contains sulfur compounds from natural and human activities, undergoes chemical transformations and transport.
- **Soil:** Present in organic matter and minerals, influenced by weathering and atmospheric deposition.
- **Aquatic Environments:** Occurs in dissolved forms, contributes to biochemical processes, affects nutrient cycling.
- **Biota:** Incorporated into organisms, essential for protein synthesis, energy metabolism, cellular function.

❑ **Flow Processes:**

- **Volcanic Eruptions:** Volcanic activity releases sulfur gases, ash, and aerosols into the atmosphere, contributing to atmospheric sulfur concentrations and global sulfur cycling. Sulfur dioxide emitted during eruptions reacts with atmospheric components to form sulfate aerosols, which can influence climate, air quality, and atmospheric chemistry.
- **Biological Processes:** Sulfur undergoes microbial transformations in soil, sediments, and water bodies through biochemical pathways such as sulfate reduction, sulfur oxidation, and organic sulfur metabolism. Sulfate-reducing bacteria (SRB) convert sulfates to sulfides under anaerobic conditions, while sulfur-oxidizing bacteria (SOB) oxidize sulfides to sulfates in aerobic environments.
- **Sulfur Cycling in Aquatic Ecosystems:** Sulfur compounds cycle between dissolved, particulate, and gaseous phases in freshwater and marine habitats, driven by microbial activity, chemical reactions, and physical processes. Sulfate reduction and sulfide oxidation occur in sediments, influencing nutrient availability, water quality, and benthic habitats.
- **Anthropogenic Activities:** Human activities like fossil fuel combustion, industrial processes, and agricultural practices release sulfur compounds into the environment, contributing to sulfur pollution, acid deposition, and ecosystem disturbance. Sulfur emissions from power plants, vehicles, and factories can result in acid rain, soil acidification, and aquatic ecosystem impairment.

❑ **Exchanges:**

- **Atmospheric Deposition:** Sulfur compounds are deposited from the atmosphere to terrestrial and aquatic ecosystems through dry deposition (particle settling) and wet deposition (precipitation). Sulfur deposition can fertilize soils, acidify water bodies, and affect plant productivity, microbial communities, and ecosystem structure.

- **Sulfur Uptake and Assimilation:** Plants and microorganisms assimilate sulfur from soil and water sources through root uptake, microbial symbiosis, and enzymatic pathways. Sulfur is incorporated into organic compounds like proteins, enzymes, and secondary metabolites, contributing to plant growth, nutrition, and defence mechanisms.
- **Sulfur Cycling in Soil:** Sulfur undergoes transformations in soil ecosystems through microbial metabolism, organic matter decomposition, and mineral weathering processes. Sulfur compounds are mineralized, immobilized, or leached from soils, influencing nutrient availability, soil fertility, and plant-soil interactions.
- **Human Impact:** Anthropogenic sulfur emissions alter the natural sulfur cycle, leading to environmental consequences such as air pollution, acidification, and ecosystem disruption. Regulatory measures, emission controls, and technological advancements are implemented to mitigate sulfur pollution and promote sustainable sulfur management.

❑ **Other Important Components:**

- **Sulfur Sinks:** Sulfur sinks are reservoirs that sequester or immobilize sulfur from the environment, including soil organic matter, sedimentary rocks, and sulfate minerals. Sulfur is stored in stable forms in soil organic matter and mineral fractions, where it undergoes slow turnover and long-term storage.
- **Sulfur Sources:** Sulfur sources are reservoirs that release sulfur into the environment through natural and anthropogenic processes, such as volcanic eruptions, weathering of sulfur-containing rocks, and combustion of fossil fuels. Sulfur sources contribute to atmospheric sulfur concentrations, deposition patterns, and biogeochemical cycling.
- **Biogeochemical Feedbacks:** Changes in sulfur cycling can impact ecosystem dynamics, biogeochemical processes, and environmental health through feedback mechanisms. Sulfur availability influences plant productivity, microbial diversity, and ecosystem resilience, while sulfur pollution affects air quality, water resources, and human well-being.

Thus biogeochemical cycles are vital for maintaining Earth's ecosystems, orchestrating the flow of essential elements like carbon, nitrogen, oxygen, phosphorus, and sulfur. Through intricate interactions between living organisms and the environment, these cycles regulate nutrient availability, energy flow, and ecological stability, highlighting their critical importance in sustaining life on our planet.

IGNITE YOUR MIND

Nature's Recycling Plant & Symphony of Cycles: Unveiling the Secrets of Biogeochemical Flows

Beyond the visible, what unseen cycles sustain life on Earth? Explore the intricate dance of biogeochemical cycles, like the water and nitrogen cycles, and their role in maintaining the delicate balance of the ecosystem.

ECOLOGICAL SUCCESSION

Ecological succession is the gradual and predictable process of change in the species composition and structure of an ecosystem over time. It occurs in response to disturbances or changes in environmental conditions, leading to the colonization, establishment, and replacement of different plant and animal species. Ecological succession can be classified into two main types: **primary succession and secondary succession.**

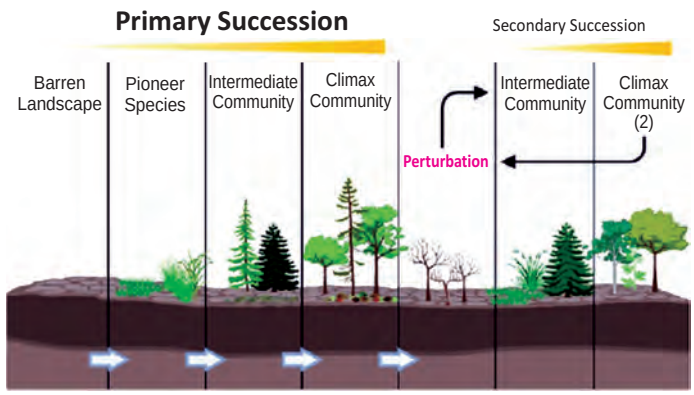


Fig. 1.27: Ecological Succession

❑ **Primary Succession:**

- Primary succession occurs in areas where no soil or living organisms exist, such as on bare rock surfaces, sand dunes, or newly formed volcanic islands. **It begins with the colonization of pioneer species,** such as lichens and mosses, which can grow on bare rock and start the process of soil formation through their decomposition.
- Over time, as organic matter accumulates and soil develops, more complex plant species, including grasses, shrubs, and eventually trees, can establish themselves. These early successional species are often adapted to harsh environmental conditions and are characterized by rapid growth rates and short life cycles.
- As the soil becomes deeper and more fertile, and environmental conditions become more stable, the composition of plant and animal species gradually changes. **Eventually, a stable and diverse community known as a climax community forms.** This climax

community represents the endpoint of primary succession and is typically dominated by long-lived tree species adapted to the prevailing climate and soil conditions.

- An example of primary succession is the colonization of **barren lava fields by pioneer plant species such as lichens and mosses,** followed by the establishment of grasses and shrubs, and eventually the growth of forests over centuries or millennia.

❑ **Secondary Succession:**

- Secondary succession occurs in areas where soil and some vegetation remain intact after a disturbance, such as after a forest fire, flood, or human activity like logging or agriculture. Unlike primary succession, **secondary succession begins with the re-establishment of plant and animal communities in an area that was previously inhabited.**
- Pioneer species, such as annual plants, grasses, and fast-growing shrubs, colonize the disturbed area and quickly take advantage of available resources. These early successional species prepare the soil and create conditions favorable for the growth of more complex vegetation.
- Over time, as soil fertility improves and environmental conditions stabilize, larger and more long-lived plant species, including trees, begin to establish themselves. The composition of plant and animal species gradually changes, eventually leading to the development of a mature and diverse community similar to that of the original ecosystem.
- An example of secondary succession is the **regeneration of a forest after a wildfire. Pioneer species like fire-adapted grasses and shrubs** quickly colonize the burned area, followed by the gradual reestablishment of tree species over decades or centuries, leading to the recovery of a mature forest ecosystem.

Pioneer Community

- A pioneer community refers to the **initial stage of ecological succession,** characterized by the colonization of barren or disturbed habitats by hardy and fast-growing species known as pioneer species. **These species are typically the first to colonize the area** due to their ability to tolerate harsh environmental conditions, such as extreme temperatures, limited nutrients, and lack of soil.
- Pioneer species play a crucial role in preparing the habitat for the establishment of more complex plant and animal communities by facilitating soil formation, nutrient cycling, and habitat creation. They often have short life cycles and reproduce rapidly, enabling them to quickly colonize and stabilize the environment.
- Examples of pioneer species include **lichens, mosses, algae, certain grasses, and herbaceous plants.** These species are adapted to thrive in environments with minimal resources and are capable of breaking down rocks and organic matter to initiate soil formation.

Climax Community

- A climax community represents the **final stage of ecological succession,** characterized by a stable and mature ecosystem that has reached a state of dynamic equilibrium under prevailing environmental conditions. In a climax community, the composition and structure of plant and animal communities remain relatively stable over time, with minimal changes occurring in species composition.
- The climax community **represents the endpoint of succession in a particular habitat,** where the community has maximized its use of available resources, and the total biomass and species diversity have reached a relatively stable state. However, it's important to note that climax communities are not static and can still undergo minor changes or disturbances, but they generally return to a stable state over time.
- Examples of climax communities include **old-growth forests, mature grasslands, coral reefs, and other diverse and stable ecosystems** that have undergone succession and reached a state of ecological balance.

Seral stage

- A seral stage in ecological succession refers to **a distinct and temporary phase within the process of succession,** characterized by specific species composition and environmental conditions.
- It represents an intermediate stage between the initial colonization of pioneer species and the establishment of a stable climax community.
- Each seral stage contributes to the gradual transition of the ecosystem towards its final, mature state through predictable changes in species composition and ecosystem structure.

The distinction between primary and secondary succession lies in their starting points. Secondary succession begins on soil that is already formed at the site. As a result, secondary succession is relatively faster as compared to primary succession, which often requires hundreds of years to establish.

Did You Know?

In grasslands, the transition from grasses to trees in ecological succession is restricted by water scarcity and frequent fires. Limited water availability hinders tree establishment, while frequent fires prevent their growth by consuming seedlings. These factors maintain the dominance of grasses, shaping the distinct biodiversity and ecological structure of grassland landscapes.

Autogenic and Allogenic Succession

Autogenic succession, driven by internal ecosystem changes, and allogenic succession, initiated by external disturbances, are two primary processes shaping ecological communities. While autogenic succession arises from factors within the ecosystem, such as soil development and plant interactions, allogenic succession results from external events like fire or flooding.

- **Autogenic Succession:**
  - Autogenic succession, also known as primary succession, occurs when ecological changes are driven primarily by the actions and interactions of the organisms themselves within an ecosystem.
  - **Example:** Autogenic succession can be observed on newly formed volcanic islands. As lava cools and solidifies, pioneer species like lichens and mosses begin to colonize the barren rock surfaces. Over centuries, soil accumulates, allowing grasses, shrubs, and eventually trees to take root. This process transforms the barren volcanic landscape into a diverse and mature ecosystem.
- **Allogenic Succession:**
  - Allogenic succession, also known as secondary succession, occurs when ecological changes are driven primarily by external factors such as disturbances or environmental changes.
  - These disturbances can include events like wildfires, hurricanes, floods, or human activities like deforestation or agriculture. Unlike autogenic succession, where the ecosystem begins with no soil, allogenic succession occurs in areas where soil is already present but has been disturbed or altered.
  - Following a disturbance, the existing community is disrupted, and opportunistic species, often from nearby areas, rapidly colonize the disturbed site. Over time, these pioneer species are replaced by more competitive and shade-tolerant species, leading to the recovery of the ecosystem and the eventual establishment of a new climax community.
  - **Example:** Allogenic succession can be observed in a forest ecosystem following a wildfire. The fire clears vegetation and recycles nutrients, creating an open habitat. Pioneer species such as grasses, herbs, and shrubs quickly colonize the burned area. Over time, as soil conditions improve and shade-tolerant species like saplings and young trees establish themselves, the forest undergoes succession, eventually returning to a mature forest ecosystem.

Autotrophic and Heterotrophic Succession

- Autotrophic succession refers to ecological changes primarily driven by the growth and development of autotrophic organisms like plants, which create conditions conducive for further ecological development.
- Heterotrophic succession, on the other hand, involves changes in the ecosystem primarily influenced by the activities of heterotrophic organisms, such as decomposers, which break down organic matter and modify environmental conditions for subsequent community development.

Overall, ecological succession is a dynamic process that plays a crucial role in shaping the structure and function of ecosystems over time. It represents nature's way of restoring and regenerating ecosystems in response to disturbances, and it highlights the resilience and adaptability of plant and animal communities to changing environmental conditions.

IGNITE YOUR MIND

Unveiling the Hidden Forces: Ecological Succession

Ecosystems are not static, but dynamic entities undergoing constant change. Explore the fascinating phenomenon of ecological succession, where pioneer species pave the way for climax communities. How does ecological succession, from barren rock to flourishing forest, paint a story of resilience and adaptation in the face of change?

BIODIVERSITY AND INTERACTION

Biodiversity refers to the variety and variability of life forms on Earth, including all living organisms, their genetic diversity, and the ecosystems in which they occur. It encompasses the diversity of species, their genetic makeup, and the variety of habitats and ecosystems in which they live. Biodiversity is often described at three levels:

- **Species Diversity:** This refers to the variety of species present in a particular area or ecosystem. It includes both the number of different species (species richness) and their relative abundance (species evenness). High species diversity indicates a rich array of different organisms coexisting within an ecosystem.
- **Genetic Diversity:** Genetic diversity encompasses the variety of genetic information contained within individuals of a species. It includes differences in DNA sequences, alleles, and genetic traits among individuals within a population. Genetic diversity is crucial for the adaptability and resilience of species to changing environmental conditions and for the long-term survival of populations.

❑ **Ecosystem Diversity:** Ecosystem diversity refers to the variety of habitats, ecological communities, and ecological processes occurring within a particular geographic area. It includes diverse terrestrial, aquatic, and marine ecosystems such as forests, grasslands, wetlands, coral reefs, and lakes. Ecosystem diversity provides a range of services and benefits essential for human well-being, including food and freshwater provision, climate regulation, nutrient cycling, and cultural and recreational opportunities.

Species Diversity

Species diversity refers to the variety and abundance of different species within a particular ecosystem or habitat. It is one component of biodiversity, which encompasses a variety of life forms, including genetic diversity, species diversity, and ecosystem diversity.

Types of Species

Species diversity is a cornerstone of biodiversity, encompassing various types of organisms crucial for ecosystem health. Understanding these diverse species types is essential for effective conservation and management strategies.

❑ **Native Species:**

- Native species are those that naturally occur and have evolved in a particular ecosystem or geographic region.
- They play essential roles in maintaining ecosystem functions and processes.
- In India, examples of native plant species include Neem (Azadirachta indica) and Mango (Mangifera indica), while native animal species include Bengal Tiger (Panthera tigris tigris) and Indian Elephant (Elephas maximus indicus).

❑ **Introduced Species:**

- Introduced species, also known as exotic or non-native species, are species that have been transported by humans from their native habitats to new geographic areas where they establish populations.
- Introduced species can sometimes outcompete native species and disrupt ecosystem balance.
- Common examples of introduced plant species in India are Lantana (Lantana camara) and Eucalyptus (Eucalyptus spp.), while introduced animal species include the House Sparrow (Passer domesticus) and Common Myna (Acridotheres tristis).

❑ **Endemic Species:**

- Endemic species are species that are found exclusively within a specific geographic area and are not naturally found anywhere else in the world.
- They are often vulnerable to habitat loss, fragmentation, and other threats.
- These species often evolve unique adaptations to their local environment and play important ecological roles within their ecosystems.
- Endemic species are often vulnerable to habitat loss, climate change, and other threats because their restricted ranges make them more susceptible to extinction.
- Some endemic plant species in India include the Nilgiri Tahr (Nilgiritragus hylocrius) and the Western Ghats Black Bulbul (Hypsipetes ganeesa), while endemic animal species include the Andaman Nicobar Flying Fox (Pteropus faunulus) and the Jerdon's Courser (Rhinoptilus bitorquatus).

❑ **Keystone Species:**

- Keystone species are species that have a disproportionately large impact on the structure and function of an ecosystem relative to their abundance.
- Despite their low abundance or biomass, keystone species play critical roles in maintaining ecosystem stability and biodiversity. Their presence or absence can significantly affect the diversity and stability of the ecosystem.Keystone species are species whose presence or absence has a disproportionate impact on the structure and function of an ecosystem.
- Examples of keystone species include predators that control prey populations, species that modify habitats, and mutualistic species that facilitate interactions among other organisms. The Indian Elephant (Elephas maximus indicus) is considered a keystone species in many Indian ecosystems, as its presence influences habitat structure and supports biodiversity. The Indian Bullfrog (Hoplobatrachus tigerinus) also acts as a keystone species by controlling insect populations.

❑ **Indicator Species:**

- Indicator species are species whose presence, absence, or abundance can provide information about the overall health or condition of an ecosystem.
- They are often used as indicators of environmental change, pollution, or habitat quality.
- Indicator species are species whose presence, absence, or abundance provides information about the environmental conditions or health of an ecosystem.
- These species are often sensitive to changes in environmental factors such as pollution, habitat degradation, or climate change.
- By monitoring indicator species, scientists and conservationists can assess the status of ecosystems and identify potential threats or disturbances.
- The Ganges River Dolphin (Platanista gangetica) serves as an indicator species for the health of freshwater ecosystems in India, while the Nilgiri Langur (Trachypithecus johnii) indicates the health of forest habitats in the Western Ghats.

❑ **Invasive Species:**

- Invasive species are non-native species that have been introduced to a new habitat and rapidly spread, often causing harm to native species, ecosystems, and human activities.
- They can outcompete native species, disrupt ecosystem processes, and lead to economic losses.
- Invasive species management often involves efforts to control or eradicate populations, prevent further introductions, and restore affected ecosystems.
- Invasive plant species in India include Water Hyacinth (Eichhornia crassipes) and Parthenium (Parthenium hysterophorus), while invasive animal species include the African Catfish (Clarias gariepinus) and the American Bullfrog (Lithobates catesbeianus).

❑ **Flagship Species:**

- Flagship species are charismatic or iconic species that are chosen to represent broader conservation initiatives or campaigns.
- They serve as symbols for conservation efforts and help raise awareness and support for biodiversity conservation.
- The Bengal Tiger (Panthera tigris tigris) is a flagship species in India, representing efforts to conserve large carnivores and their habitats. The Indian Peacock (Pavo cristatus) is another flagship species symbolizing the conservation of biodiversity in India.

❑ **Umbrella Species:**

- Umbrella species are species whose conservation benefits a wide range of other species that share the same habitat or ecosystem.
- By protecting umbrella species and their habitats, conservation efforts indirectly benefit many other species within the ecosystem.
- The Asian Elephant (Elephas maximus) acts as an umbrella species in India, with conservation efforts benefiting numerous other species that share its habitat, such as Indian Rhinoceros (Rhinoceros unicornis) and Bengal Tiger (Panthera tigris tigris).

IGNITE YOUR MIND

Biodiversity: A Tapestry of Life's Variations

From the majestic tiger to the microscopic bacteria, what is the true essence of biodiversity, and how does it contribute to the resilience and adaptability of ecosystems?

Adaptation in Species

Adaptation is a fundamental process through which organisms evolve traits that enhance their survival and reproduction in their environment. These adaptations can occur at various levels, from physiological and behavioral traits to morphological characteristics. Different species exhibit a wide range of adaptations tailored to their specific ecological niches and environmental challenges. Here are some common types of adaptation observed in different species:

❑ **Physiological Adaptations:**

- **Thermoregulation:** Many species have evolved mechanisms to regulate their body temperature, such as sweating in mammals and basking in reptiles. Example:
  - ❐ Polar bears have a thick layer of blubber and dense fur to insulate them from the cold Arctic environment.
  - ❐ Cacti have adapted to hot, arid environments by storing water in their succulent stems and reducing water loss through specialized stomata.
- **Osmoregulation:** Aquatic organisms, like fish, have specialized organs and processes to maintain water and salt balance in their bodies. Example:
  - ❐ Marine fish, such as sharks, have specialized salt-secreting cells in their gills to maintain proper salt balance in their bodies.
  - ❐ Mangrove trees have specialized roots that can excrete excess salt, allowing them to survive in brackish water habitats.
- **Metabolic adaptations:** Some species have adapted to survive in extreme environments with limited resources by adjusting their metabolic rates, such as hibernation in mammals and estivation in amphibians. Example:
  - ❐ Some desert rodents, like kangaroo rats, have evolved efficient kidneys that produce highly concentrated urine to conserve water.
  - ❐ Alpine plants produce antifreeze proteins that prevent ice crystal formation in their cells, allowing them to survive freezing temperatures.

❑ **Behavioral Adaptations:**

- **Migration:** Many species, including birds, fish, and mammals, migrate over long distances in response to seasonal changes or resource availability. Example:
  - ❐ Monarch butterflies migrate thousands of kilometers between North America and Mexico to avoid harsh winters and find suitable breeding grounds.
  - ❐ Some desert plants, like tumbleweeds, disperse their seeds by rolling along the ground, utilizing wind to find new areas for growth.
- **Hibernation and Dormancy:** Certain animals, such as bears and ground squirrels, enter a state of dormancy or hibernation to conserve energy during periods of food scarcity or harsh weather conditions. Example:
  - ❐ Ground squirrels hibernate during the winter months, lowering their metabolic rate and conserving energy until food becomes more abundant.

- Deciduous trees shed their leaves and enter a period of dormancy during the winter to conserve water and energy.

- **Social behavior:** Species like ants, bees, and wolves exhibit complex social structures and behaviors that enhance cooperation, communication, and division of labor within their groups. Example:
  - African elephants live in matriarchal herds led by an older female, who coordinates group activities such as foraging and caring for the young.
  - Some tree species, like acacias, release chemical signals to alert nearby plants of herbivore attacks, allowing them to produce defensive compounds.

❑ **Morphological Adaptations:**

- **Camouflage:** Some species have evolved coloration or patterns that allow them to blend into their surroundings, making them less visible to predators or prey. Example:
  - Stick insects have evolved body shapes and colors that mimic twigs or leaves, helping them blend into their surroundings and avoid detection by predators.
  - Orchids have flowers that resemble certain pollinators, such as bees or wasps, increasing the likelihood of successful pollination.
- **Structural adaptations:** Species living in specific habitats may have physical features that help them exploit resources or avoid predators, such as the long neck of giraffes for browsing tall trees. Example:
  - Birds of prey, like eagles and hawks, have sharp talons and hooked beaks for capturing and tearing apart their prey.
  - Water lilies have broad, flat leaves that float on the surface of ponds, maximizing exposure to sunlight for photosynthesis.
- **Appendages and organs:** Organisms have adapted various appendages and organs for specific functions, such as the wings of birds for flight or the fins of fish for swimming.

❑ **Reproductive Adaptations:**

- **Flowering and fruiting strategies:** Plants have evolved diverse strategies for reproduction, including flowering at specific times or producing fruits with adaptations for dispersal by animals. Example:
  - Bees and butterflies are attracted to brightly colored flowers with sweet nectar, facilitating pollination as they transfer pollen between plants.
  - Dandelions produce fluffy seeds that are dispersed by the wind, allowing them to colonize new areas quickly.
- **Courtship rituals:** Many animal species exhibit elaborate courtship behaviors and displays to attract mates and ensure successful reproduction. Example:
  - Male peacocks display their vibrant tail feathers in elaborate courtship displays to attract mates and establish dominance.
  - Some flowering plants release fragrant scents or pheromones to attract pollinators and enhance successful fertilization.
- **Parental care:** Species may invest in parental care behaviors, such as nesting, feeding, or protecting offspring, to increase their survival chances. Example:
  - Emperor penguins take turns incubating their eggs and caring for their chicks in harsh Antarctic conditions, ensuring the survival of their offspring.

❑ **Ecological Adaptations:**

- **Feeding specialization:** Species may adapt to specific diets or foraging strategies to exploit available food sources efficiently, such as herbivores with specialized digestive systems for processing plant material. Example:
  - Koalas have specialized digestive systems adapted to detoxify and digest the toxins found in eucalyptus leaves, their primary food source.
  - Carnivorous pitcher plants have modified leaves that form pitfall traps to capture and digest insects for additional nutrients.
- **Habitat specialization:** Organisms may adapt to thrive in particular habitats or microhabitats, such as desert-dwelling plants with succulent leaves for water storage or deep-sea creatures with bioluminescent organs for communication in low-light environments. Example:
  - Polar bears are uniquely adapted to Arctic ice floes, with large paws for swimming and hunting seals, and thick fur and blubber for insulation.
  - Epiphytic orchids grow on the branches of trees in tropical rainforests, utilizing aerial roots to extract water and nutrients from the air and debris.

Homeostasis

❑ Homeostasis is the physiological process by which organisms maintain a stable internal environment despite external changes. It involves the regulation of various factors such as body temperature, pH levels, blood pressure, and nutrient levels within narrow ranges to ensure optimal conditions for cellular function and survival.

❑ In simpler terms, homeostasis is like the body's internal thermostat, constantly working to keep things balanced. When external conditions fluctuate, the body initiates responses to counteract these changes and restore equilibrium.

❑ For example, when the body temperature rises due to exposure to hot weather or physical activity, mechanisms like sweating and vasodilation (expansion of blood vessels) are activated to dissipate heat and cool the

body down. Conversely, if the body temperature drops, mechanisms such as shivering and vasoconstriction (narrowing of blood vessels) help conserve heat and raise the temperature.

- Homeostasis is essential for the proper functioning of cells, tissues, organs, and organ systems. Disruptions to homeostasis can lead to various health problems and diseases.

Speciation

Speciation is the process by which new species arise from a single ancestral species over time. It is a fundamental concept in evolutionary biology and occurs when populations of a species become reproductively isolated from each other, leading to the accumulation of genetic differences that eventually result in the formation of distinct species.There are several types of speciation, each driven by different mechanisms of reproductive isolation:

- **Allopatric Speciation:**
  - This occurs when a population becomes geographically isolated from the rest of its species, often due to physical barriers such as mountains, rivers, or other geographical features.
  - Over time, genetic differences accumulate in the isolated population through mutation, genetic drift, and natural selection, leading to reproductive isolation and the eventual formation of new species.
  - **Example:** Darwin's finches in the Galápagos Islands.
- **Sympatric Speciation:**
  - In sympatric speciation, new species arise within the same geographical area without physical separation.
  - This can occur through various mechanisms such as polyploidy (the presence of multiple sets of chromosomes), habitat differentiation, or disruptive selection.
  - **Example:** The apple maggot fly (Rhagoletis pomonella), which evolved to specialize on different host plants within the same area.
- **Parapatric Speciation:**
  - Parapatric speciation occurs when populations of a species are distributed along a geographical gradient, with limited gene flow between adjacent populations. Over time, genetic differences accumulate, leading to reproductive isolation and the formation of distinct species.
  - **Example:** The ring species of salamanders in the Ensatina complex, where adjacent populations can interbreed, but distant populations cannot.
- **Peripatric Speciation:**
  - Peripatric speciation is similar to allopatric speciation but involves a small population becoming isolated on the edge of the species' range.
  - This small founder population experiences genetic drift and rapid evolution due to its small size, leading to the formation of a new species distinct from the ancestral population.
  - **Example:** The island populations of the Anolis lizard in the Caribbean.
- **Adaptive Radiation:**
  - Adaptive radiation occurs when a single ancestral species rapidly diversifies into a variety of ecological niches, often following colonization of new habitats or the evolution of key innovations.
  - This can lead to the emergence of numerous new species, each adapted to exploit different resources within the environment.
  - **Example:** The finches of the Galápagos Islands, which diversified into various species with different beak shapes and sizes to exploit different food sources.

Each type of speciation contributes to the incredible diversity of life on Earth and provides insight into the processes driving evolutionary change.

RELATED TOPICS

Population Ecology

- A population comprises organisms residing in the same area and reproducing with each other; they are of the same species. **'Conspecifics'** refer to organisms belonging to the same species.
- The boundaries of a population can be either natural or artificial. Artificial boundaries include man-made structures, roads, and mowed grass, while natural boundaries can be rivers, mountains, or deserts.
- Population ecology research primarily focuses on understanding the number of individuals inhabiting a region and the factors influencing population size fluctuations over time.

Example: The population of Bengal Tigers in India refers to the collective group of all individual Bengal Tigers living within the country's boundaries. This population encompasses tigers inhabiting various habitats across India, including national parks, wildlife reserves, forests, and grasslands. Researchers and conservationists study this population to understand its size, distribution, genetic diversity, behavior, and threats.

Deep Ecology and Shallow Ecology

Deep ecology and shallow ecology are two contrasting perspectives or approaches to environmental philosophy and environmentalism, each with its own set of principles and values.

- **Deep Ecology:**
  - Deep ecology is a philosophical and environmental movement that emphasizes the intrinsic value of nature and the interconnectedness of all living beings.

- It advocates for a fundamental shift in human attitudes and values towards nature, promoting an ecocentric worldview where humans are seen as part of, rather than separate from, the natural world.
- Deep ecologists argue for the **protection of nature and biodiversity for their own sake, not just for human benefit,** and advocate for the preservation of wilderness areas and the restoration of degraded ecosystems.
- Key principles of deep ecology include biospheric egalitarianism (recognizing the inherent worth of all living beings), decentralization of human society, and voluntary simplicity (reducing human consumption and materialism).

❑ **Shallow Ecology:**

- Shallow ecology, also known as anthropocentric environmentalism, is a more anthropocentric approach to environmentalism that **focuses primarily on human interests and concerns.**
- It tends to **prioritize human needs and economic growth over environmental protection and conservation,** viewing nature primarily as a resource to be exploited for human benefit.
- Shallow ecologists may advocate for conservation measures and sustainable development, but their primary motivation is often to maintain human well-being rather than protect nature for its own sake.
- This perspective may overlook or undervalue the intrinsic worth of non-human species and ecosystems, leading to a more utilitarian approach to environmental management and policy.

ECOLOGICAL PRODUCTIVITY

Ecological productivity refers to the rate at which energy is captured, stored, and converted into organic matter by producers (such as plants and algae) through photosynthesis or chemosynthesis within an ecosystem. It is a fundamental aspect of ecosystem function and is essential for supporting life on Earth.

Ecological productivity is typically measured in terms of primary productivity and secondary productivity.

❑ **Primary Productivity:** Primary productivity is the rate at which producers (autotrophic organisms) convert solar energy into organic compounds through photosynthesis or chemosynthesis. It represents the synthesis of organic matter from inorganic substances and is the foundation of the food chain. Primary productivity is usually measured in terms of biomass or energy production per unit area per unit time (e.g., grams of carbon per square meter per year).

- **Gross Primary Productivity (GPP):** GPP is the total amount of organic matter produced by producers through photosynthesis or chemosynthesis. It represents the total energy captured by autotrophs.
- **Net Primary Productivity (NPP):** NPP is the amount of organic matter that remains after subtracting the energy used by producers for respiration (cellular metabolism) from the GPP. NPP represents the energy available to support heterotrophic organisms (consumers) and is a key determinant of ecosystem productivity.

❑ **Secondary Productivity:** Secondary productivity refers to the rate at which consumers (heterotrophic organisms) convert organic matter into biomass through consumption and assimilation of primary producers or other consumers. It represents the synthesis of new biomass by heterotrophs and is influenced by factors such as resource availability, trophic interactions, and ecosystem stability.

- **Consumer efficiency:** Consumer efficiency refers to the proportion of energy ingested by consumers that is converted into new biomass through growth and reproduction. It is influenced by factors such as metabolic efficiency, digestive efficiency, and energy losses through respiration and excretion.

❑ Ecological productivity varies across different ecosystems and can be influenced by environmental factors such as temperature, precipitation, nutrient availability, and light intensity. Mangroves, grasslands, lakes, and oceans represent the decreasing order of productivity in these ecosystems.

❑ High levels of ecological productivity support diverse and abundant communities of organisms, while low productivity may limit the carrying capacity of an ecosystem and constrain ecosystem services such as food production, nutrient cycling, and habitat provision.

Therefore, understanding and monitoring ecological productivity is essential for assessing ecosystem health, biodiversity conservation, and sustainable resource management.

ECOLOGICAL COMMUNITY

An ecological community, or simply a community, refers to the **assemblage of different species of organisms** living and interacting with each other within a defined geographic area or habitat. These interactions can include various types of relationships such as competition, predation, mutualism, and parasitism. Ecological communities can range in size from small microhabitats to large ecosystems, and they can be found in diverse environments such as forests, grasslands, aquatic ecosystems, and even urban areas.

The Structure and Characteristics of an Ecological Community

The structure and characteristics of an ecological community refer to the organization, composition, and dynamics of the various species of organisms within a defined geographic area or habitat. Here are the key aspects of community structure and characteristics:

- **Species Composition:** The species composition of a community refers to the identities and abundance of different species present within it. Communities can vary in **species richness** (the number of different species found in a community) and **species evenness** (the relative abundance of each species at a given site).
- **Species Diversity:** Species diversity is a measure of the variety and abundance of species within a community. It includes both species richness and species evenness and is an important indicator of community health and resilience.
- **Trophic Structure:** The trophic structure of a community refers to the organization of species into different trophic levels based on their feeding relationships. This includes producers (autotrophs), consumers (heterotrophs), and decomposers, which form food chains and food webs within the community.
- **Spatial Distribution:** The spatial distribution of species within a community refers to how individuals of different species are distributed across the landscape or habitat. This can vary from random to clumped to uniform distribution patterns, depending on factors such as resource availability, habitat structure, and species interactions.
- **Ecological Interactions:** Ecological interactions such as competition, predation, mutualism, and parasitism play a crucial role in shaping community structure and dynamics. These interactions influence species distribution, abundance, and coexistence within the community.
- **Successional Dynamics:** Succession refers to the process of ecological change over time in which a series of different species replace each other in a predictable sequence. Communities can undergo primary succession (on bare substrates) or secondary succession (following disturbance) leading to the development of stable and mature ecosystems.
- **Functional Roles:** Each species within a community occupies a specific ecological niche, which describes its functional role and interactions within the ecosystem. These roles contribute to ecosystem functioning, including processes such as nutrient cycling, energy flow, and habitat provision.
- **Temporal Dynamics:** Community structure and composition can change over time in response to factors such as seasonal variations, environmental changes, and disturbances. Understanding these temporal dynamics is essential for predicting and managing community responses to environmental change.

Overall, the structure and characteristics of a community are shaped by interactions among species and their environment, and understanding these aspects is crucial for conservation, ecosystem management, and understanding the functioning of ecosystems.

Habitat and Ecological Niche

- **Habitat:**
  - A habitat refers to the **specific physical environment** where an organism lives and carries out its life activities.

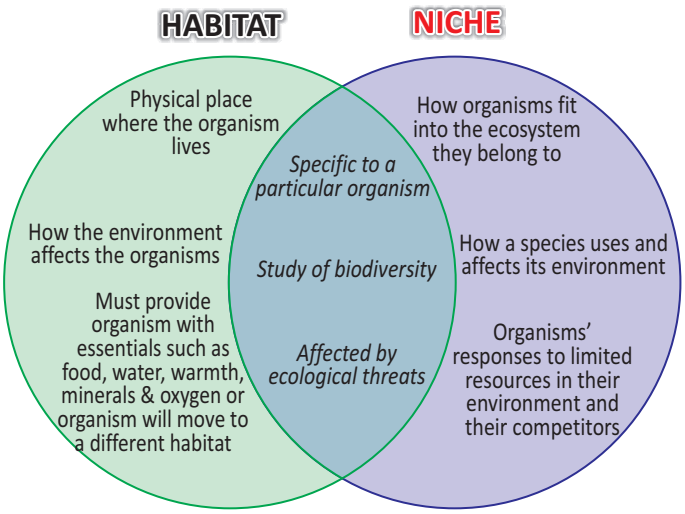

HABITAT
NICHE
Physical place where the organism lives
How organisms fit into the ecosystem they belong to
Specific to a particular organism
How the environment affects the organisms
Study of biodiversity
How a species uses and affects its environment
Must provide organism with essentials such as food, water, warmth, minerals & oxygen or organism will move to a different habitat
Affected by ecological threats
Organisms' responses to limited resources in their environment and their competitors

Fig. 1.28: Habitat and Ecological Niche

  - It includes both biotic (living) and abiotic (non-living) factors that provide the necessary resources and conditions for the organism's survival, growth, and reproduction.
  - Examples of habitat factors include climate, soil type, vegetation, water availability, and other organisms present in the environment.
  - Organisms are adapted to their specific habitats, and different species may inhabit different types of habitats based on their physiological and behavioral requirements.
- **Ecological Niche:**
  - Ecological niche refers to the **role and position of an organism within its habitat,** including how it interacts with other organisms and its physical environment.
  - It encompasses the full range of biotic and abiotic factors that influence the organism's survival and reproduction, as well as its interactions with other species.
  - The ecological niche of a species includes its feeding habits, preferred habitat types, reproductive behaviors, predator-prey relationships, and other ecological interactions.
  - Each species has a unique ecological niche, which helps to determine its place in the ecosystem and its impact on other species.
  - The concept of the ecological niche is dynamic and can change over time in response to environmental changes, competition, predation, and other ecological factors.

Ecological Stratification

Ecological stratification refers to the division of ecosystems into distinct layers or zones based on various environmental factors such as light availability, temperature, moisture, and nutrient distribution. These layers can be both vertical and horizontal, contributing to the overall structure and complexity of the ecosystem. Here's a breakdown of vertical and horizontal ecological stratification:

- **Vertical Ecological Stratification:** Vertical ecological stratification refers to the layering of ecosystems along a vertical gradient, typically observed in terrestrial and aquatic environments. It involves the division of the habitat into distinct vertical zones, each characterized by unique environmental conditions and species compositions. **Common examples of vertical stratification include:**

Fig.1.29: Vertical Ecological Stratification

  - **Canopy Layer:** The uppermost layer of vegetation in forests, consisting of tall trees that form a dense canopy.
  - **Understory Layer:** The intermediate layer beneath the canopy, characterized by shorter trees, shrubs, and saplings.
  - **Herbaceous Layer:** The ground-level layer consisting of herbaceous plants, grasses, ferns, and groundcover vegetation.
  - **Forest Floor:** The lowest layer of the forest ecosystem, composed of leaf litter, decaying organic matter, and soil.
- **Horizontal Ecological Stratification:** Horizontal ecological stratification refers to the division of ecosystems into distinct zones or habitats based on horizontal spatial variation. Unlike vertical stratification, which is primarily based on altitude or depth, horizontal stratification considers factors such as topography, soil type, water availability, and vegetation patterns across the landscape. **Examples of horizontal stratification include:**

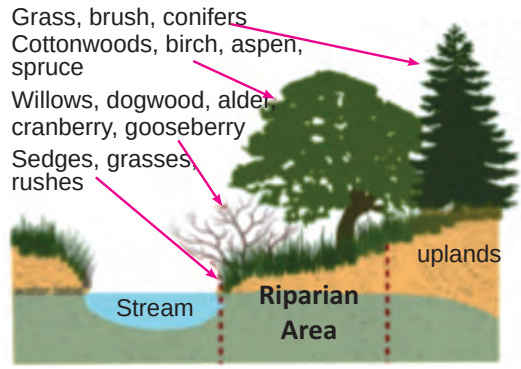


Fig. 1.30: Horizontal Ecological Stratification

  - **Riparian Zones:** Transitional areas between terrestrial and aquatic ecosystems, typically found along riverbanks, streams, and wetlands.
  - **Microhabitats:** Small-scale variations within an ecosystem, such as rock crevices, fallen logs, tree hollows, and patches of vegetation.

Overall, both vertical and horizontal ecological stratification play important roles in shaping the structure, function, and dynamics of ecosystems, influencing species distribution, interactions, and ecosystem processes.

Ecological Dominance

- Ecological dominance refers to the degree of influence or control that a particular species or group of species exerts over the structure, composition, and function of an ecosystem in comparison to other species present in the same habitat.
- It is a concept used to describe the significance of a species in shaping ecological patterns and processes within a community or ecosystem.
- Ecological dominance can manifest in various forms, including:
  - **Numerical Dominance:** Some species may occur in significantly higher numbers or abundance compared to others in the same habitat. Numerically dominant species can significantly influence ecosystem dynamics and resource availability, impacting the distribution and abundance of other species through competition, predation, or facilitation.
    - An example of numerical dominance is seen in the African savanna, where the wildebeest (Connochaetes taurinus) often occurs in large herds, outnumbering other herbivores like zebras and gazelles. Their high abundance influences grazing patterns, nutrient cycling, and predator-prey dynamics in the ecosystem.
  - **Functional Dominance:** Certain species may play critical roles in ecosystem processes and functions, such as nutrient cycling, energy flow, or habitat modification. These functionally dominant species often have specialized traits or ecological functions that make them essential for maintaining ecosystem stability and resilience.

- In freshwater ecosystems, cyanobacteria such as Microcystis aeruginosa can exhibit functional dominance by forming harmful algal blooms. These cyanobacteria produce toxins and alter water chemistry, impacting the health of aquatic organisms and ecosystem functioning.

- **Structural Dominance:** Some species may exert dominance through their physical structure or habitat-forming abilities, shaping the physical environment and providing habitat for numerous other species. For example, dominant tree species in a forest ecosystem can create canopy cover, influence microclimate conditions, and provide resources for understory plants and animals.
  - In tropical rainforests, emergent trees like the kapok tree (Ceiba pentandra) can exert structural dominance. These towering trees create a canopy that shades the forest floor, influencing light availability, temperature, and humidity. Their large trunks and branches provide habitats for epiphytes, birds, and other organisms.
- **Temporal Dominance:** Species dominance can also vary over time, with certain species becoming dominant during specific seasons or environmental conditions. Temporal dominance can influence ecosystem dynamics, succession, and species interactions over different time scales.
  - Along coastlines, the intertidal zone experiences temporal dominance as different species become prevalent during low and high tides. For example, during low tide, barnacles and mussels dominate the rocky shore, while during high tide, seaweeds and crabs become more abundant, shaping community structure and resource availability.

Ecological dominance is essential for ecosystem management, conservation, and restoration efforts. Identifying dominant species and understanding their ecological roles can inform strategies for preserving biodiversity, managing invasive species, and promoting ecosystem resilience in the face of environmental change.

Dominant Species vs Keystone Species

Dominant species are those that are abundant in a particular habitat and play a significant role in shaping its structure and composition through their sheer numbers or habitat modification. On the other hand, **keystone species** are those that have a disproportionately large impact on their ecosystem relative to their abundance, often exerting critical ecological roles that are essential for maintaining biodiversity and ecosystem function. While dominant species may be numerically common, keystone species are indispensable for ecosystem stability and resilience.

In **Indian forests,** a common example of a dominant species is the **Indian teak** (Tectona grandis), which often forms dense stands and dominates the canopy layer, influencing the availability of light, moisture, and nutrients for other species. An example of a keystone species in India is the **Indian elephant** (Elephas maximus), which plays a crucial role in maintaining forest ecosystems by dispersing seeds, creating habitat niches through their foraging activities, and influencing vegetation structure through browsing and trampling.

Ecological Community's Seasonal and Diurnal Fluctuations

Seasonal and diurnal fluctuations are essential aspects of ecological communities, reflecting the dynamic nature of ecosystems in response to changing environmental conditions over both daily and yearly cycles.

❑ **Seasonal Fluctuations:**

- **Temperature Variation:** Seasons bring about changes in temperature, influencing the metabolic rates and activity patterns of organisms within the ecological community. For example, many species exhibit seasonal migrations, hibernation, or dormancy to cope with temperature fluctuations.
  - In India, seasonal temperature fluctuations influence species like the Indian red panda, which migrates to higher elevations during warmer months to escape heat stress.
- **Precipitation Patterns:** Seasonal changes in precipitation levels affect water availability and habitat conditions, influencing the distribution and abundance of aquatic and terrestrial species. Droughts and rainy seasons can impact breeding, foraging, and migration behaviors of organisms.
  - Monsoon rains in India affect species like the Indian bullfrog, triggering breeding events and influencing its distribution in wetland habitats.
- **Vegetation Dynamics:** Seasonal fluctuations in light intensity and temperature drive changes in plant growth, flowering, and fruiting cycles. These changes in vegetation structure and phenology can impact herbivores, pollinators, and seed dispersers within the community.
  - Seasonal changes in light and temperature impact Indian mango trees, affecting flowering and fruiting cycles crucial for pollinators and frugivores.
- **Breeding and Reproduction:** Many species exhibit seasonal breeding patterns, synchronized with optimal environmental conditions for offspring survival and resource availability. Seasonal fluctuations in breeding behavior can influence population dynamics and community composition.

- Indian peafowls time their mating rituals with the arrival of the monsoon, ensuring optimal conditions for raising chicks.

❑ **Diurnal Fluctuations:**

- **Light Availability:** Diurnal fluctuations in light intensity and duration influence photosynthesis, activity patterns, and behavior of both plants and animals. Nocturnal species are active during the night, utilizing moonlight or artificial light sources, while diurnal species are active during the day.
  - Indian palm civets are nocturnal, relying on moonlight in dense forests for hunting and navigation, while Indian mynas are diurnal, foraging during daylight hours.
- **Temperature Fluctuations:** Daily changes in temperature affect physiological processes, metabolism, and activity levels of organisms. Many species exhibit thermoregulatory behaviors to cope with temperature fluctuations, such as basking in the sun or seeking shade.
  - Desert species like the Indian spiny-tailed lizard exhibit basking behavior in the morning to raise body temperature before seeking shade during hot afternoons.
- **Predator-Prey Dynamics:** Diurnal fluctuations in predator and prey activity can influence foraging behavior, hunting strategies, and predator avoidance mechanisms. Some species may alter their activity patterns to avoid predation during peak activity periods of predators.
  - Diurnal fluctuations influence the hunting patterns of Indian leopards, with increased activity during dusk and dawn to capitalize on prey movement.
- **Resource Utilization:** Diurnal fluctuations in resource availability, such as food and water, can drive temporal patterns of feeding, drinking, and competition among species. Some organisms may exhibit crepuscular behavior, being most active during dawn and dusk when resource availability is high.
  - Indian langurs exhibit crepuscular behavior, feeding on leaves and fruits during early morning and late afternoon when canopy resources are most accessible.

Overall, seasonal and diurnal fluctuations play integral roles in shaping ecological communities, influencing species interactions, population dynamics, and ecosystem processes. Understanding these temporal patterns is crucial for studying biodiversity, ecosystem functioning, and responses to environmental change.

The Range of Tolerance and Maximum Range

The Range of Tolerance and Maximum Range are concepts used in ecology to describe an organism's ability to withstand variations in environmental factors.

❑ **Range of Tolerance:**

- The Range of Tolerance refers to the **range of environmental conditions within which an organism can survive, grow, and reproduce.** It encompasses the minimum and maximum values of various environmental factors, such as temperature, humidity, pH, salinity, and nutrient levels, that an organism can tolerate.
- Organisms have specific physiological limits beyond which they cannot survive or function optimally.
- The Range of Tolerance **defines the boundaries within which an organism can maintain homeostasis and carry out essential life processes.**
- Different species have different ranges of tolerance for various environmental factors, and these ranges may overlap with those of other species.
- Factors such as genetic adaptation, acclimatization, and evolutionary history influence an organism's range of tolerance.

❑ **Maximum Range:**

- The Maximum Range refers to the **upper limit of an organism's tolerance to a particular environmental factor.**
- It represents the highest value of that factor that an organism can withstand without experiencing adverse effects on its survival or fitness.
- Beyond the maximum range, an organism may experience physiological stress, reduced growth rates, decreased reproductive success, or even mortality.
- Factors such as heat stress, extreme pH levels, or toxic concentrations of pollutants can exceed an organism's maximum range of tolerance.
- Understanding an organism's maximum range is crucial for predicting its response to environmental changes, such as climate change or pollution, and for assessing its vulnerability to habitat degradation or anthropogenic disturbances.

❑ **Temperature Tolerance:** Organisms have specific temperature ranges within which they can thrive. This includes their tolerance to both high and low temperatures. For example, extremophiles such as thermophiles can survive in extreme heat, while cold-adapted organisms like polar bears can withstand freezing temperatures.

- **Maximum Range of Temperature Tolerance:** The upper limit of temperature beyond which an organism can no longer maintain its physiological processes due to denaturation of proteins or metabolic inefficiency.
- **Minimum Range of Temperature Tolerance:** The lower limit of temperature below which an organism's metabolic rates decrease, enzyme activity slows down, and cellular processes become impaired, leading to reduced growth or survival.

- **pH Tolerance:** pH tolerance refers to an organism's ability to tolerate variations in the acidity or alkalinity of its environment. Different organisms have different pH tolerances depending on their physiological adaptations. For instance, some fish species can tolerate acidic conditions in acidic lakes or rivers, while others thrive in alkaline environments such as coral reefs.
  - **Maximum Range of pH Tolerance:** The upper limit of pH beyond which an organism experiences cellular and enzymatic dysfunction due to the disruption of ion balance, protein denaturation, and interference with metabolic processes.
  - **Minimum Range of pH Tolerance:** The lower limit of pH below which an organism's cellular membranes and proteins are compromised, leading to metabolic inhibition, impaired nutrient uptake, and physiological stress.
- **Salinity Tolerance:** Salinity tolerance relates to an organism's ability to tolerate variations in salt concentration in water or soil. Some organisms, like halophytes, can survive in highly saline environments such as salt marshes or saline soils, while others, like freshwater fish, require low salinity levels to thrive.
  - **Maximum Range of Salinity Tolerance:** The upper limit of salt concentration beyond which an organism experiences osmotic stress, cellular dehydration, and ion imbalance, leading to reduced growth, impaired reproduction, and ultimately death.
  - **Minimum Range of Salinity Tolerance:** The lower limit of salt concentration below which an organism experiences osmotic imbalance, leading to cellular swelling, disrupted ion transport, and metabolic dysfunction, affecting its physiological processes.

In conclusion, the study of life forms and Earth's ecology reveals the intricate relationships between organisms and their environment. Understanding the principles of ecology, from individual organisms to the biosphere, elucidates the dynamics of ecosystems and the services they provide. Biotic and abiotic components interact in complex ways, sustaining biodiversity and ecosystem functions. However, contemporary challenges such as habitat destruction, pollution, and climate change threaten these delicate balances. Moving forward, conservation efforts, sustainable practices, and global cooperation are essential to mitigate these threats and ensure the resilience and health of Earth's ecosystems for future generations.

IGNITE YOUR MIND

Emerging Trends and Debates: Navigating the Crossroads of Ecology and Environment

From climate change to invasive species, what are the pressing ecological challenges of our time, and how can we navigate the complex ethical and scientific debates surrounding them?

This chapter covered the complex network of life forms and how they interact with each other in Earth's ecosystems. Gaining knowledge of ecology can help one understand the dynamic interactions that exist between living things and their surroundings. Every ecological level, from the individual to the biosphere, provides a different perspective on the complexity of life on Earth. Because different species interact with one another and adapt to their surroundings, biodiversity is essential to the formation of ecosystems. However, there are serious threats to biodiversity from modern problems like pollution, habitat loss, and climate change. In order to preserve our planet's rich ecological legacy for future generations, it is critical that conservation efforts be given top priority going forward, along with the promotion of sustainable practices and international cooperation.

Terrestrial Ecosystems

2

INTRODUCTION

Terrestrial ecosystems encompass a **diverse range of habitats found on land,** ranging from forests and grasslands to deserts and tundra. These ecosystems play a **crucial role in supporting life on Earth,** providing habitat for countless species and contributing to essential ecological processes. They play an integral part in regulating climate patterns, nutrient cycling and soil formation.

Human activities such as deforestation, urbanisation and agriculture pose significant threats to the integrity of terrestrial ecosystems. **Understanding and conserving these ecosystems** are essential for maintaining biodiversity and ensuring the sustainability of our planet.

NATURAL ECOSYSTEM

- All that is deemed "natural" originates and persists in nature devoid of human influence. Consequently, a natural ecosystem comprises organisms collaborating with each other and their environment to thrive and evolve.

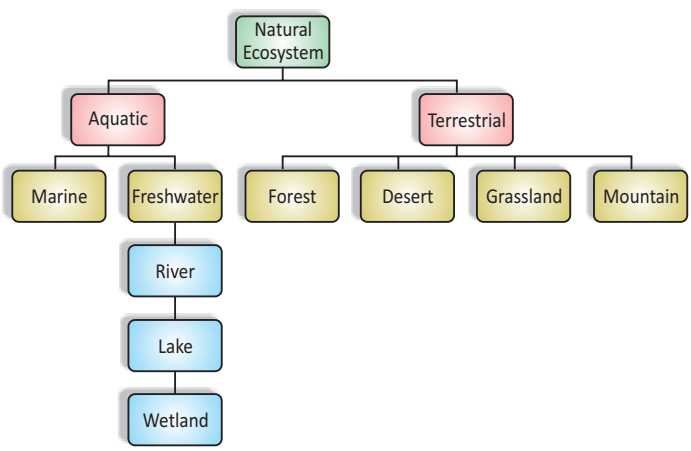


Fig 2.1: Classification of Natural Ecosystem

- A natural ecosystem comprises a collection of plants and animals that operate as a cohesive unit and can sustain its distinct identity, such as forests, grasslands, estuaries, and more. It relies entirely on solar energy for its functioning.

Earth's Natural Ecosystems are Categorized into Two Main Types

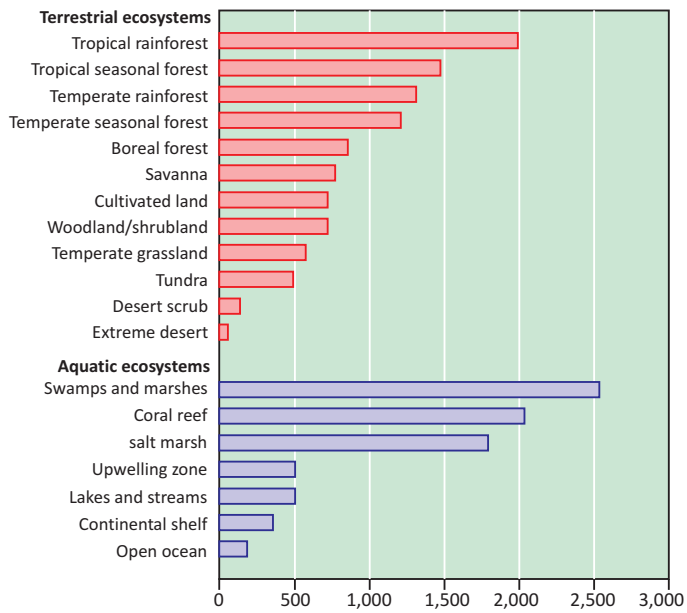


Fig 2.2: Net Primary Productivity (g C/m^2/year)

- **Terrestrial Ecosystems:** Terrestrial ecosystems can be defined as a community of interaction between many living organisms and nonliving things on land.
- **Aquatic Ecosystems:** Unlike terrestrial ecosystems found on land, aquatic ecosystems are those that thrive within and adjacent to bodies of water. These ecosystems comprise interconnected communities of organisms dependent on each other and their aquatic environment for sustenance and survival.

Aspect	Aquatic Ecosystems	Terrestrial Ecosystems
Habitat	Consists of water bodies like oceans, rivers, lakes, and ponds.	Comprises land surfaces, including forests, grasslands, deserts, and mountains.
Primary Producers	Mainly algae, phytoplankton, and aquatic plants.	Primarily composed of grasses, trees, shrubs and other terrestrial plants.
Primary Consumers	Include zooplankton, fish, aquatic insects and mollusks.	Comprising herbivores like insects, birds, mammals and reptiles.

Secondary Consumers	Predatory fish, larger aquatic insects, and carnivorous mammals like otters.	Predators such as carnivorous mammals (e.g., lions, wolves), birds of prey and snakes.
Oxygen Availability	Dissolved oxygen in water for aquatic organisms.	Atmospheric oxygen for terrestrial organisms.
Adaptations	Aquatic organisms have specialized structures like gills for respiration and fins for locomotion in water.	Terrestrial organisms have features like lungs for respiration and limbs for movement on land.
Threats	Pollution, habitat destruction, overfishing and climate change.	Deforestation, habitat fragmentation, pollution, and climate change.
Examples	Coral reefs, oceans, rivers, ponds and mangrove forests.	Rainforests, savannas, tundras, deserts and grasslands.

TERRESTRIAL ECOSYSTEMS

Terrestrial ecology encompasses the intricate **connections between living organisms and their surrounding environment** on land. Variations in topographical characteristics such as valleys, mountains and slopes lead to distinct differences.

- These variances manifest in both material and biological diversities. **Changes in altitude and latitude contribute to shifts in climate patterns,** consequently affecting the flora and fauna found in different terrestrial regions.
- This diversity leads to the segmentation of ecosystems within the broader biosphere. **Moisture and temperature are identified as the primary limiting factors** influencing terrestrial ecosystems.
- **Unique Characteristics:** Each biome possesses distinct attributes, including climate (primarily precipitation and temperature), vegetation, animal populations and soil composition.

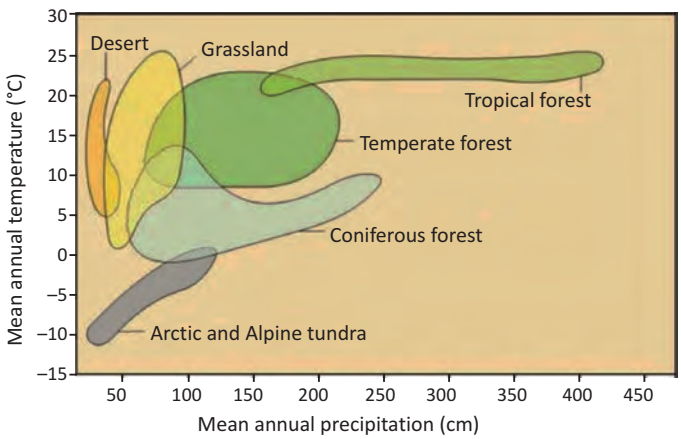


Fig. 2.3: Terrestrial Ecosystems

TYPES OF TERRESTRIAL ECOSYSTEMS

Terrestrial ecosystems are ecosystems that exist on land and include both living and non-living things. The four major types of terrestrial ecosystems are: Forest, Grasslands, Desert and Mountains.

Ecosystem	Forest	Grassland	Desert	Mountain
Climate	Varied, with distinct seasons; temperate, tropical, boreal forests. High precipitation in tropical, moderate in temperate, and low in boreal.	Varies widely; temperate grasslands experience four seasons, tropical savannas have wet and dry seasons.	Hot and arid; low precipitation, high temperatures during the day, and cooler nights.	Varied; temperature decreases with elevation, creating different zones such as alpine and subalpine.
Vegetation	Dense trees, diverse plant species, and multiple canopy layers. Includes epiphytes, buttress roots, and understory plants.	Dominated by grasses, occasional trees, and shrubs. Adapted to frequent grazing and wildfires.	Sparse vegetation adapted to arid conditions; succulents, xerophytic plants, and drought-resistant shrubs.	Sparse vegetation adapted to altitude; cold-resistant plants such as conifers, alpine flowers.
Biodiversity	High biodiversity due to complex structure and niches; numerous plant and animal species.	Moderate biodiversity with a mix of herbivores, carnivores, and omnivores; fewer tree species.	Low biodiversity due to extreme conditions; specialized flora and fauna adapted to survive.	Moderate biodiversity, with unique species adapted to high altitudes and harsh climates.

Ecosystem	Forest	Grassland	Desert	Mountain
Adaptation	Plants may have epiphytes (plants growing on other plants), buttress roots for support, and various canopy layers. Animals exhibit specialized behaviors to navigate the dense vegetation.	Drought-resistant grasses with deep roots; herbivores adapted to grazing; some trees may have fire-resistant adaptations.	Water-storing adaptations in plants (succulents); animals may be nocturnal to avoid extreme daytime temperatures.	Cold-resistant plants, such as conifers, and animals may hibernate or have thick fur for insulation.
Human Impact	Logging and deforestation for timber and agriculture; habitat fragmentation due to human expansion.	Agriculture, overgrazing, and urbanization leading to habitat loss; conversion to farmland.	Over-extraction of water for agriculture; habitat destruction due to mining and urban development.	Tourism, agriculture, habitat alteration for infrastructure development, leading to soil erosion.
Examples	Amazon Rainforest (South America), Boreal Forest (Canada), Deciduous Forest (Eastern U.S.).	African Savanna, North American Prairie, Pampas (South America).	Sahara Desert (Africa), Sonoran Desert (North America), Atacama Desert (South America).	Rocky Mountains (North America), Himalayas (Asia), Andes (South America).
Significance	Essential for global oxygen production Home to a vast array of plant and animal species Play a crucial role in regulating climate and maintaining biodiversity	Important for agriculture and grazing Habitat for herbivores and grazing animals Grasses play a crucial role in carbon sequestration and soil stabilization	Unique adaptations of flora/fauna for water conservation Valuable for studying climate change and arid land ecosystems	Hosts unique and diverse ecosystems Essential for maintaining biodiversity Provides habitat for a wide range of plant and animal species
Challenges	Deforestation and habitat loss Climate change and invasive species Forest fires and unsustainable practices	Overgrazing and habitat degradation Climate change and desertification Invasive species and conversion to other land uses	Climate change and desertification Resource depletion and overexploitation Land degradation and loss of fertility	Packaging waste, driven by high tourist numbers, contributes significantly to plastic pollution in mountains. Global warming-induced glacier melting in mountain regions adversely affects biodiversity.
Government Initiatives	Joint Forest Management (JFM) National Mission on Green India CAMPA (Compensatory Afforestation Fund Management and Planning Authority) Sustainable forest management practices	National Mission on Sustainable Agriculture (NMSA) Degraded Forests and Wastelands Development Mission Grazing management and rotational grazing practices	National Watershed Development Project for Sustainable Land Management (NWDPSLM) Integrated Desert Development Programme (IDDP) Sustainable water management practices and drought- resistant crops	Mission Green Himalayas Himalayan Biosphere Reserve National Mission on Himalayan Heritage Parvat Mala Programme Sustainable mountain development practices and community-based conservation

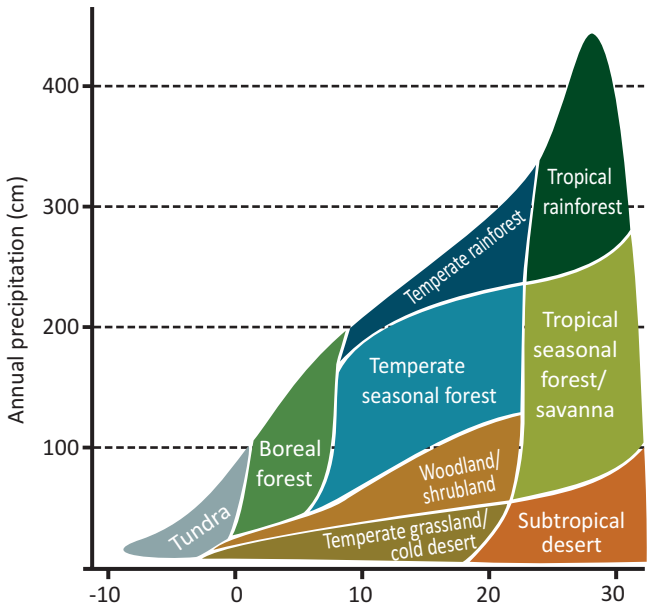
IGNITE YOUR MIND

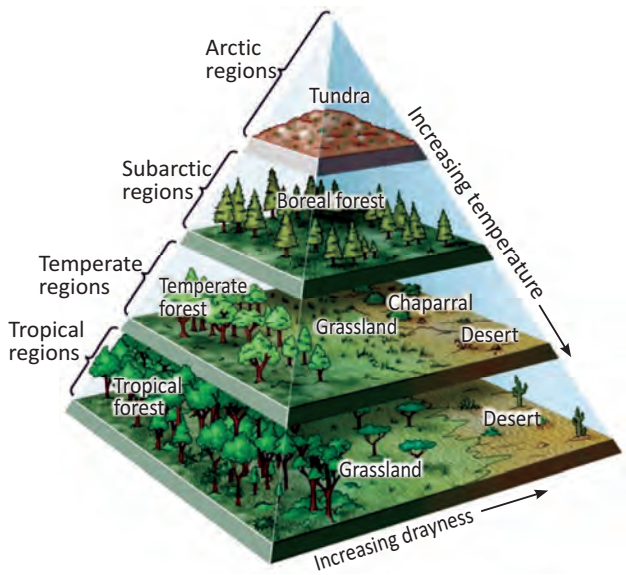
A Fragile Paradise: Protecting Mountain Ecosystems from Emerging Threats

From the relentless grip of climate change to the ever-expanding footprint of human activity, mountain ecosystems face unprecedented challenges. How can we ensure the survival of these vital landscapes and the treasures they hold, safeguarding them for future generations?

Biomes

- A biome refers to a **vast ecological community** where organisms such as plants, animals, birds, insects and humans have adapted to specific climate conditions. The Earth displays a variety of environments, which are **categorized into different biomes based on factors like** climate, temperature range, weather patterns, and climatic conditions.
- **Coined by ecologist Frederic Edward Clements** in 1916, the term "biome" is associated with the concept of a biotic community, illustrating the interrelationships among living organisms in an ecosystem.
- Each biome is unique and has its own climate (mainly precipitation and temperature), flora, fauna and soil composition.





Different vegetation patterns from the tropics to the Polar region"

Fig 2.4: Average Annual Temperature (°C)

Major types of terrestrial biomes include:

- Tropical Rain Forest Biome
- Tropical Deciduous Biome (Monsoon Climate)
- Savanna or Tropical Wet and Dry Biome
- Desert Biome

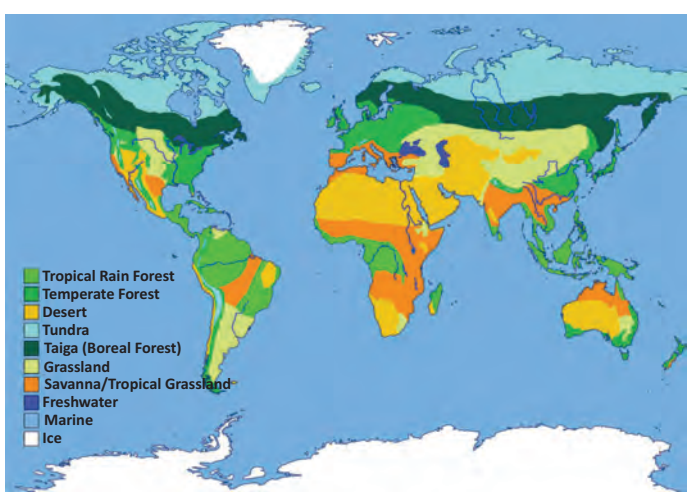


Fig. 2.5: Biomes of the World

- Temperate Deciduous Biome (Mediterranean Climate)
- Temperate Deciduous Biome (North-Western Europe – British Type Climate)
- Temperate Rainforest Biome
- Sub-Tropical Deciduous Biome in Eastern China, South Eastern USA
- Steppe or Temperate Grassland Biome
- Taiga or Boreal Biome
- Tundra Biome

Let's delve deeper into each type of biome, exploring their unique characteristics, biodiversity, significance, challenges, and specific examples.

Tropical Rainforest Biome

The tropical rainforest biome is a biome that covers about 6% of the Earth's surface but **contains about 50% of the world's species.** These forests are also known as equatorial rainforests or equatorial evergreen forests.

- **Geographical Extent:**
  - Spanning the globe around the equator, tropical rainforests cover about **7% of Earth's land surface.**
  - Major locations include the Amazon rainforest (South America), Congo rainforest (Central Africa), South-east Asian rainforests (Indonesia, Malaysia, etc.), and Madagascar.
- **Flora Characteristics:**
  - **Layered Structure:** Imagine a towering cathedral of trees forming a dense canopy, filtering sunlight below.

- **Emergent Layer:** Giants like Kapok trees reach 60-70 metres their crowns basking in sunlight.
- **Understory:** Shade-tolerant plants, vines and epiphytes (plants growing on others) thrive here.
- **Forest Floor:** Dark and damp, with decomposing leaves and specialized plants adapted to low light.
- **Vegetation Diversity:** With up to 200-300 tree species per hectare, rainforests house over half the world's plant species.
- **Examples:** Orchids, Ferns, Lichens, Mosses, Bromeliads, Rubber trees, etc.

Fig. 2.6: Tropical Rainforests across the World

❑ **Fauna Characteristics:**

- **Rich Biodiversity:** The tropical rainforest biome boasts the highest biodiversity, with millions of species thriving in diverse habitats, including the canopy, understory, and streams.
- **Vertical Stratification:** Species in the rainforest biome are vertically stratified, occupying different layers of the forest canopy, understory, and forest floor, leading to niche specialization and resource partitioning.
- **Colorful Morphology:** Many species exhibit vibrant colors, unique morphological features, and elaborate courtship displays as adaptations for communication, mate attraction, and species recognition in the dense forest environment.
- **Key Species Examples:** Monkeys, sloths, jaguars, toucans, macaws, snakes, frogs, butterflies, beetles

❑ **Adaptations:**

- **Camouflage:** Blending in with leaves or bark helps animals avoid predators.
- **Arboreal Adaptations:** Many animals are excellent climbers and leapers, utilizing the layered structure.
- **Nocturnal Activity:** Some animals avoid the heat and competition by being active at night.
- **Specialized Diets:** From fruit-eating birds to insect-consuming bats, animals have evolved diverse feeding strategies.

❑ **Other Features:**

- Tropical rainforests play a vital role in **regulating Earth's climate.** They absorb large amounts of carbon dioxide, and act as a **"carbon sink."**
- These ecosystems are threatened by deforestation, climate change and unsustainable practices. Conservation efforts are crucial to protect these irreplaceable treasures.

IGNITE YOUR MIND

Rainforest Rhapsody: Emerald Symphonies of Life

Imagine yourself transported to a world of emerald giants, sunlight filtering through a cathedral of leaves, and the air alive with the cacophony of unseen creatures. This is the rainforest, a symphony of life unlike any other. Explore the secret adaptations that allow plants and animals to thrive in this steamy, vibrant realm, where every rustle and chirp tells a story of survival and interdependence.

Tropical Deciduous Biome (Monsoon Climate)

The tropical deciduous biome, also known as the monsoon forest, is a warm climate with long dry seasons.

❑ **Geographical Extent:**

- **Southeast Asia:** India, South-east Asia, Myanmar, Thailand, Laos, Cambodia, Vietnam
- **Africa:** Madagascar, parts of East Africa and West Africa
- **Central and South America:** Tropical regions of Mexico, Central America and South America

❑ **Flora Characteristics:**

- **Dominant trees:** Teak, sal, rosewood, neem, mahogany and bamboo

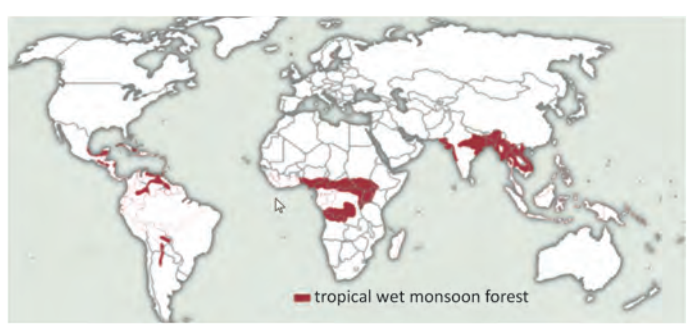


Fig 2.7: Tropical Wet Monsoon Forest

- **Seasonal shedding:** During the dry season, most trees lose their leaves to conserve water and create a visually stunning transformation.
- **Understory vegetation:** During the wet season, lush undergrowth carpets the forest floor with grasses, shrubs, and herbs.

❑ **Fauna Characteristics:**

- **Seasonal Adaptations:** Animals navigate the distinct wet and dry seasons. During the wet season, they focus on breeding, forage and growth. The dry season necessitates strategies like migration, estivation (dormancy), or maximizing water conservation.
- **Herbivore Diversity:** A wide range of herbivores feed on the abundant wet-season vegetation, featuring specialized digestive adaptations.
- **Predator Dynamics:** Predators and scavengers, from large carnivores to smaller animals, rely on herbivore populations for food, maintaining ecological balance.
- **Pollination and Seed Dispersal:** Insects, birds, and bats are crucial for plant pollination and seed dispersal, ensuring species propagation.
- **Key Species Example:**
  - ❒ **Large mammals:** Elephants, tigers, leopards, deer, monkeys, gibbons
  - ❒ **Herbivores:** Sambar deer, gaur, wild boar, antelope
  - ❒ **Carnivores:** Tigers, leopards, dholes, wolves

❑ **Adaptations:**

- **Trees:** Shedding leaves, deep root systems, thick bark for protection from fire.
- **Animals:** Seasonal migration, nocturnal activity, water-conserving mechanisms like reduced urine output.

❑ **Other Features:**

- **Importance:** These forests play a crucial role in regulating water flow, preventing soil erosion, and providing valuable resources for local communities.
- **Threats:** Deforestation, habitat fragmentation, and climate change pose major threats to these ecosystems.
- **Conservation efforts:** Protected areas, sustainable forestry practices and community-based conservation initiatives are essential for safeguarding these vital biomes.

Savannah or Tropical Wet and Dry Biome

The tropical savanna biome is also known as the tropical wet and dry biome. It is a **transitional biome between grassland and forest biomes,** and is characterized by seasonal precipitation and drought.

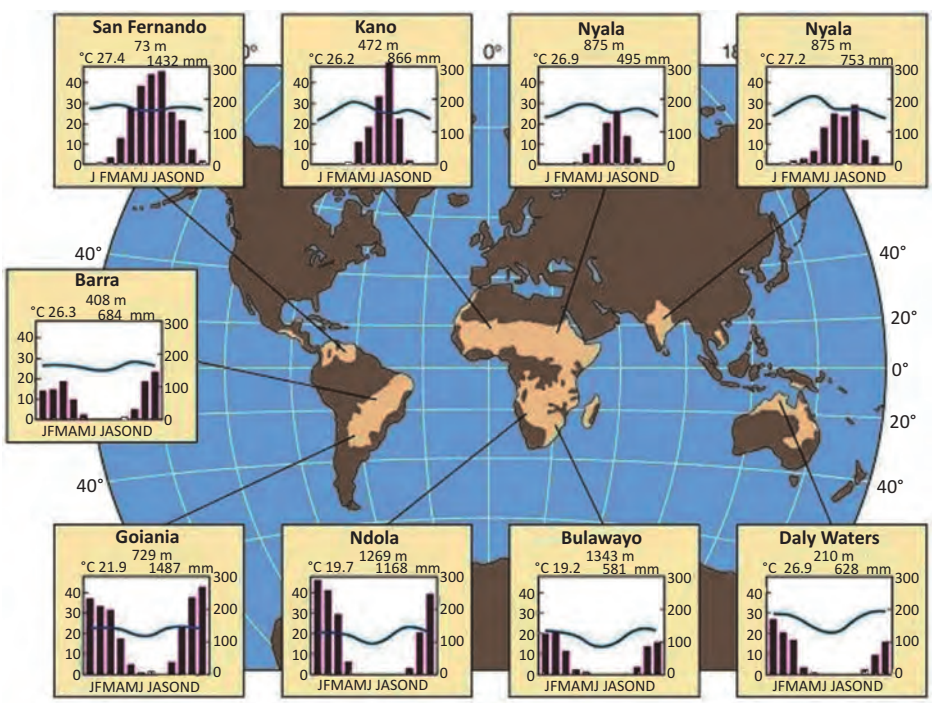


Fig. 2.8: Savannah or Tropical Wet and Dry Biome

❑ **Geographical Extent:**

- Primarily found in subtropical and tropical regions of Africa, South America, Australia, and India. Located between deserts and rainforests, usually **spanning 8° to 20° north and south of the equator.**

❑ **Flora Characteristics:**

- Dominated by grasses with scattered trees and shrubs. Vegetation composition varies based on rainfall:
  - **Wet savannas:** Taller grasses, more trees (acacias, baobabs).
  - **Dry savannas:** Shorter grasses, fewer trees, more drought-resistant shrubs.

❑ **Fauna Characteristics**

- **Herbivore Diversity:** Large grazers like zebras and wildebeests thrive on open plains, while giraffes browse leaves from taller trees. Antelopes show diverse grazing strategies.

- **Open-Area Adaptations:** Animals have keen senses and camouflage for survival in vast landscapes. Speed and agility are crucial for escape and hunting.
- **Seasonal Shifts:** Some mammals migrate following rain and grazing opportunities, while others adjust behavior seasonally for foraging and energy conservation.
- **Predator-Scavenger Relationships:** Lions and leopards hunt herbivores, while smaller predators target smaller prey. Scavengers like vultures and hyenas play vital roles in consuming carrion.
- **Key Species:** Lion, wildebeest, zebra, giraffe, elephant, cheetah.

❑ **Adaptations:**

- **Animals:** Large herbivores have long migrations to follow food sources. Predators with excellent eyesight and speed for hunting. Many animals have drought-resistant features like water conservation and efficient grazing.
- **Plants:** Grasses have deep root systems to access water during dry seasons. Trees have adaptations like thorns for protection and water storage.

❑ **Other Features:**

- **Fire** is a natural and important disturbance, shaping the ecosystem and preventing tree encroachment.

The Significance of Fire in Grassland Management

❑ **Management Importance of Fire:** Fire holds a significant role in the management of grasslands.

❑ **Influence of Fire under Varying Conditions**

- In moist conditions, fire promotes the growth of grass over trees.
- Conversely, in dry conditions, fire becomes essential to preserve grasslands from encroachment by desert shrubs.

❑ **Enhancement of Forage Yields:** Burning leads to increased forage yields in grasslands.

Desert Biome

Desert biomes are the **driest of all the biomes.** In fact, the most important characteristic of a desert is that it receives very little rainfall. Most deserts **receive less than 300 mm a year compared to rainforests, which receive over 2,000 mm.**

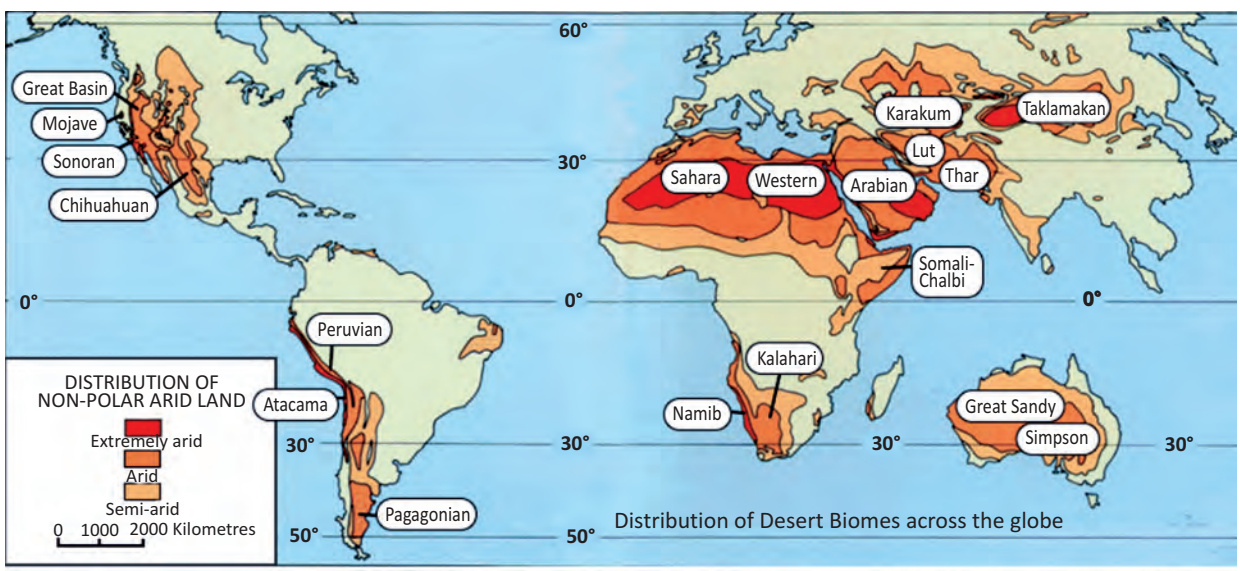


Fig. 2.9: The Deserts of the World

Geographical Extent of Major global deserts: Deserts are found on all continents except Europe, with major ones including:

❑ **Sahara Desert (Africa):** The largest hot desert, spanning over 9 million square kilometers.

❑ **Gobi Desert (Asia):** A cold desert, covering over 1.2 million square kilometers.

❑ **North American deserts:** Including the Mojave, Sonoran, and Chihuahuan deserts.

❑ **Patagonian Desert (South America):** A cold desert along the southern tip of the continent.

❑ **Australian deserts:** Arid and semi-arid, with temperatures ranging from above 10°C to over 35°C in summer. Australia is the driest inhabited continent, with around 18% of the mainland being desert.

Flora Characteristics: Due to limited water availability, desert plants are typically:

❑ **Drought-resistant:** With adaptations like waxy coatings, spines, and deep root systems.

❑ **Ephemeral:** Many only appear after infrequent rainfall.

❑ **Succulents:** Storing water in fleshy tissues.

❑ **Cacti:** Iconic desert plants with unique water-saving adaptations.

Fauna Characteristics:

- **Diverse fauna:** Despite harsh conditions, deserts support a surprising variety of animals.
- **Water conservation:** In deserts, water acquisition and retention pose constant challenges that makes animals to develop various adaptations. Desert tortoises, for instance, store water in their bladders.
- **Nocturnal Activity:** Desert animals primarily forage at night to conserve water.
- **Burrowing:** Animals seek shelter underground, offering cooler temperatures and predator protection.
- **Key Species**
  - **Reptiles:** Lizards, snakes, and tortoises, well-adapted to conserving water and heat tolerance.
  - **Mammals:** Rodents, foxes, and hoofed animals like camels and antelopes.
  - **Birds:** Vultures, owls and ground birds with efficient water use mechanisms.

Adaptation

- **Desert Plants**
  - **Predominance of Shrubs:** Desert plants primarily manifest as shrubs, aiding in water conservation.
  - **Reduced or Absent Leaves:** Many desert plants exhibit either a reduction in leaf size or a complete absence of leaves.
  - **Succulent Tissues for Water Storage:** Both leaves and stems of desert plants often possess succulent tissues, enabling water storage.
  - **Certain desert plants have chlorophyll even in their stems,** facilitating photosynthesis.
- **Desert plants typically have well-developed root systems** that spread over a large area, enhancing water absorption.
- **Desert Animals**
  - **Nocturnal Behaviour:** Many desert animals are nocturnal, avoiding the sun's heat during the day.
  - **Water Conservation:** Water conservation is facilitated through the excretion of concentrated urine.
  - **Long Limbs for Heat Regulation:** Animals often possess long legs to keep their bodies away from the hot ground.
  - **Water Acquisition from Seeds:** Herbivorous animals obtain sufficient water from the seeds they consume.

Other Features:

Desert ecosystems are dynamic and complex, with unique features depending on their location:

- **Coastal deserts:** Influenced by ocean currents and fog, supporting unique vegetation.
- **Cold deserts:** These deserts experience freezing temperatures at night, with distinct plant and animal life.
- **Polar deserts:** Found in Antarctica and the Arctic, with extreme cold and limited precipitation.

IGNITE YOUR MIND

Desert Dreams: Unveiling the Secrets of Life in the Arid Lands

Arid deserts, often perceived as barren wastelands, hold secrets waiting to be unveiled. Beyond the seemingly endless stretches of sand lie ingenious adaptations that allow plants and animals to thrive in these harsh environments. Discover the strategies employed by desert dwellers to combat scorching sun and scarce water, revealing the resilience of life against all odds.

Brief Description of Major Indian Deserts

India boasts a variety of deserts, ranging from **arid to cold climates,** each with its unique features and characteristics.

Thar Desert: It is a arid desert and it is also known as the Great Indian Desert. That desert holds the title as India's largest desert, spanning an impressive 200,000 square kilometers across India and Pakistan. Globally, it ranks as the 18th largest desert.

- **Climate:** The Thar Desert experiences severe drought conditions with scanty and irregular rainfall. Winter rains from northern India seldom reach the region. The atmosphere maintains consistently low relative humidity levels throughout the year.
- **Temperature Variations:** From November to March, extreme temperature fluctuations are common, often dipping below freezing at night. April to June witnesses intense heat, accompanied by frequent scorching winds that exacerbate the dryness.
- **Flora:** The area boasts a variety of herbaceous vegetation including **cactus, neem, khejri, and acacia nilotica,** all of which exhibit adaptability to extreme temperatures and challenging climatic conditions.
- **Fauna:** The desert ecosystem is home to a diverse array of wildlife inhabitants, including the **leopard, Asiatic wild cat (Felis silvestris ornata), chousingha (Tetracerus quadricornis), chinkara (Gazella bennettii), Bengal desert fox (Vulpes bengalensis), Blackbuck (antelope),** and numerous reptile species.

Cold Deserts

- Cold deserts in India encompass regions such as Ladakh, Leh and Kargil in Kashmir. Also include the Spiti Valley in Himachal Pradesh, along with some parts of northern Uttarakhand and Sikkim.
- Cold deserts showcase a distinctive array of **characteristics** that distinguish them within the spectrum of ecosystems:

- **Sub-Zero Temperatures:** Cold deserts frequently experience temperatures below the freezing point, impeding plant water absorption and contributing to the overall aridity of these environments.
- **Limited Rainfall:** Characterized by a meager mean annual rainfall, typically less than 400 mm, cold deserts resemble traditional deserts with scarce precipitation and consequent water scarcity.
- **Pronounced Snowfall:** A notable feature of cold deserts is the occurrence of heavy snowfall, typically observed from late November to early April, further complicating survival strategies for organisms inhabiting these regions.
- **Susceptibility to Wind Erosion:** With minimal vegetation cover and a dry atmosphere, cold deserts are susceptible to wind erosion, with constant sand and soil particle movement shaping the landscape over time.
- **Sandy, Alkaline Soil:** Cold desert soils commonly exhibit sandy to sandy loam textures, often with a neutral to slightly alkaline pH. These soils possess limited organic matter content and struggle with water retention.

IGNITE YOUR MIND

From Lush Jungles to Barren Deserts: A Tale of Two Extremes

Can you imagine two seemingly alien landscapes – a rainforest teeming with life and a desert parched under the relentless sun – sharing the same classification: terrestrial ecosystems? Delve deeper and discover the fundamental characteristics that bind these contrasting environments, revealing the hidden threads that connect all life on Earth.

Temperate Deciduous Biome (Mediterranean Climate)

The temperate deciduous biome (Mediterranean climate) is characterized by **trees with small, broad leaves that are widely spaced and not very tall.** The vegetation in this biome is mixed, with evergreen and deciduous trees. The trees are short, with thick, waxy leaves. Rugged mountains, rolling hills, and coastal plains create diverse microclimates influencing local precipitation and temperature variations.

- **Geographical Extent:** The Temperate Deciduous Biome is found primarily in five distinct regions around the world, all located between 30° and 40° north and south latitudes:
  - **Mediterranean Basin:** This includes countries bordering the Mediterranean Sea, such as Spain, Italy, Greece, Turkey and northern Africa.

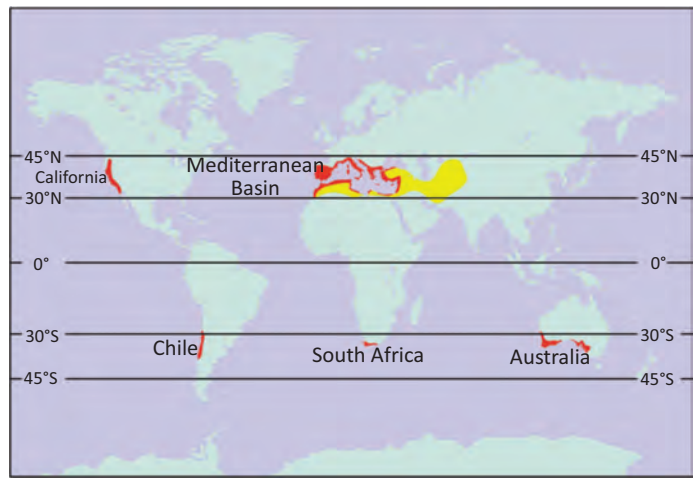


Fig 2.10: World Distribution of Temperate Deciduous Biome

  - **California Chaparral and Oak Woodlands:** This region stretches along the coast of California in the United States.
  - **Central Chile:** This includes the central portion of Chile in South America.
  - **South-western Africa:** This encompasses parts of South Africa, Namibia and Angola.
  - **South-western Australia:** This covers the south-western corner of Australia.
- **Flora Characteristics:**
  - **Dominant vegetation type:** Broad-leaved deciduous trees. These trees lose their leaves during the dry summer months to conserve water.
  - **Common Tree Species:** Oak (various species), Cork oak, Olive, Eucalyptus, Laurel, Maple, Beech, Elm, Chestnut.
  - **Shrubs:** Chaparral, Sagebrush, Manzanita, Broom, Gorse.
  - **Grasses:** Wild Oats, Barley, Fescues.
- **Fauna Characteristics:**
  - **Seasonal Strategies:** Animals adapt through aestivation, migration and hibernation to cope with seasonal changes in temperature and water availability.
  - **Dietary Adaptations:** Herbivores consume moisture-rich vegetation, while insectivores rely on insects as a water-rich food source and predators obtain water from their prey.
  - **Thermoregulation Mechanisms:** Animals utilize features like light-colored fur, burrowing behavior, and reduced mid-day activity to regulate body temperature and conserve water.
  - **Camouflage and Defense:** Species employ camouflage, defensive structures like spines and thorns, and toxic defenses to evade predators and ensure survival in their habitat.

- **Key Species**
  - **Mammals:** Deer, Wild boar, Rabbit, Fallow deer, Red fox, Coyote, Badger, Skunk, Hedgehog.
  - **Birds:** Eagle, Hawk, Owl, Vulture, Songbird (variety of species), Hummingbird (California), Bee-eater (Mediterranean).
  - **Reptiles:** Snake, Lizard, Tortoise, Gecko.

❑ **Adaptations**

- **Plants:**
  - **Leaf Adaptations:** Plants develop small, leathery leaves and waxy coatings to minimize water loss and reflect sunlight.
  - **Deep Root Systems:** Plants grow deep roots to access underground water reserves during dry periods.
  - **Fire Resistance:** Some plants have fire-resistant bark or seeds to survive wildfires.
- **Animals:**
  - **Nocturnal Behavior:** Animals are active at night to avoid daytime heat.
  - **Burrowing:** Animals burrow to escape heat and conserve water.
  - **Water Conservation:** Animals concentrate urine to minimize water loss.

Temperate Deciduous Biome (North-Western Europe – British Type Climate)

The temperate deciduous biome in north-western Europe has a British type climate. This biome has **hot summers and cold winters,** with average daily temperatures ranging from -30°C (-22°F) to 30°C (86°F). The **average annual temperature ranges from -4° to 8°C.]**

❑ **Geographical Extent:** This biome stretches across Northwestern Europe, encompassing regions with a British Type Climate. This climate is characterized by cool, wet winters and mild, rainy summers. Key areas include:

- **United Kingdom:** England, Wales, Scotland (excluding northernmost highlands)
- **France:** Brittany, Normandy, northern and western regions
- Belgium, Netherlands, Jutland Peninsula (Denmark), Coastal Areas of Western Norway and Northwest Iberia

Fig. 2.11: Extent of Temperate Deciduous Biome across the Globe

❑ **Flora Characteristics:**

- **Dominant vegetation:** Deciduous broad-leaved trees, shedding leaves in autumn to conserve energy during winter.
- **Understory:** Shrubs, grasses, wildflowers, ferns.
- **Seasonal variation:** Spring brings vibrant wildflowers, summer boasts lush green foliage, autumn explodes with colorful leaves, and winter sees bare branches and dormant plants.
- **Common species:** Oak, Ash, Beech, Birch, Elm, Hornbeam, Poplar, Lime, Chestnut, Maple.

❑ **Fauna Characteristics:**

- **Year-Round Feeding:** Diverse diet includes plants, insects, and smaller animals. Predators rely on keen senses, herbivores focus on varied vegetation. Opportunistic feeding maximizes food abundance.
- **Camouflage:** Cryptic coloring and mimicry helps animals to blend in. Seasonal changes aid in defense against predators.
- **Shelter Use: Animals** utilize burrows, tree cavities, and dens for protection and breeding. Nesting sites serve as safe havens for young.
- **Breeding and Migration:** Spring breeding aligns with abundant food. Some migrate or adapt altitude based on seasonal conditions.
- **Key Species**
  - **Mammals:** Red deer, Roe deer, Wild boar, Badger, Fox, Hedgehog.
  - **Birds:** Robin, Wren, Blackbird, Song thrush.
  - **Amphibians:** Common frog, Common toad, Newts etc.
  - **Reptiles:** Grass snake, Slowworm, Common lizard.

❑ **Adaptations:**

- **Plants:** Deciduous leaves minimize water loss in winter and maximize sunlight capture in summer. Deep root systems access water and nutrients. Bark provides insulation.
- **Animals:** Hibernation or migration during winter for some species. Thick fur or feathers for insulation. Camouflage for protection. Food hoarding for winter.

❑ **Other Features:**

- **Human impact:** This biome has been heavily influenced by human activity, with agriculture, forests and urbanization reducing natural forest cover and impacting fauna. Conservation efforts are crucial.
- **Importance:** These forests provide valuable ecosystem services like water purification, flood control, carbon sequestration, and habitat for diverse species.

Temperate Rainforest Biome

Although relatively small in terms of area covered, the primary expanse of this biome is situated along the northwestern coast of North America, spanning from northern California through southern Alaska.

- **Geographical Extent:** Found primarily in mid-latitude zones between 40° and 60° north and south, these rainforests hug coastlines:

Fig. 2.12: Temperate Rainforest Biome

  - **North America:** Pacific coast from Northern California to Alaska
  - **South America:** Valdivian eco-region in Chile and Argentina
  - **Europe:** Western coasts of Ireland, Scotland, Norway, and Scandinavia
  - **Oceania:** Southeast Australia, Tasmania and New Zealand
- **Flora Characteristics:** Dominated by broad-leaved evergreen trees, these rainforests boast:
  - **Towering giants:** Redwoods, Douglas firs, Sitka spruces reaching 60-100 meters
  - **Dense understory:** Ferns, mosses, shrubs creating a lush green carpet
  - **Epiphytes:** Bromeliads, mosses and orchids clinging to branches for moisture and nutrients
- **Fauna Characteristics:**
  - **Mammal Diversity:** Compared to tropical rainforests, temperate rainforests have fewer mammals due to simpler vegetation layers and seasonal vegetation. In summer, animals in this biome feed on winged seeds and walnuts, which can be stored for a long time.
  - **Fruit Ripening:** Fruits from rose trees, apple trees, gooseberries, Hawthorne and others ripen around the same time (late summer) and are used for fat storage during summer.
  - **Diverse Animal Life:** There is a wide variety of life in temperate rainforests, including frogs, turtles, insects, birds, spiders and salamanders.
- **Adaptations:** Species in these rainforests have adapted to:
  - **Cool temperatures:** Thick fur, feathers, or blubber for insulation
  - **Seasonal changes:** Hibernation or migration in some animals
  - **Abundant moisture:** Broad leaves for efficient water absorption, webbed feet or fins for aquatic environments
- **Other Features:**
  - **Coastal influence:** Fog, salt spray, and proximity to the ocean shape these ecosystems.
  - **High productivity:** Due to ample rainfall and mild temperatures, these forests are some of the most productive on Earth.
  - **Threats:** Logging, deforestation, and climate change pose significant challenges.

Sub-Tropical Deciduous Biome in Eastern China, South Eastern USA

Luxuriant vegetation characterizes this biome, primarily located in **Eastern China and the Southeastern USA.**

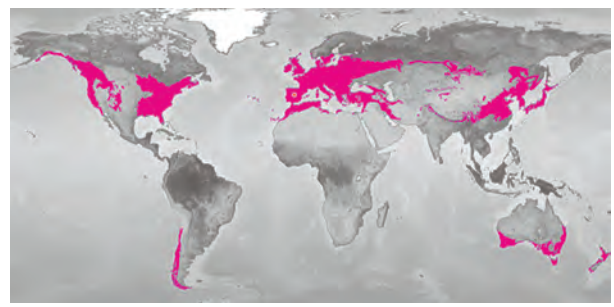


Fig. 2.13: Tropical Deciduous Biome

- **Geographical Extent:**
  - **Asia:** Northern India, Eastern China, South-east Asia
  - **Southern North America:** South-eastern United States, Mexico
  - **South America:** Eastern Argentina, Paraguay, Southern Brazil
  - **Africa:** Eastern and Southern Africa, Madagascar
  - **Australia:** Eastern and South-eastern Australia
- **Flora Characteristics:**
  - **Broad, flat leaves:** Maximize light capture during the wet season.
  - **Shallow root systems:** Efficiently absorb water during the rainy months.
  - **Drought-resistant adaptations:** Thick bark, waxy leaves, and reduced leaf size minimize water loss in the dry season.
  - **Examples:** Oaks, Maples, Hickories, Teak, Sal, Eucalyptus.
- **Fauna Characteristics:**
  - **Impact of Canopy:** The yearly change in canopy cover affects animal life in deciduous forests.
  - **Amphibious Creatures:** Due to shelter and access to moisture. Salamanders are a common sight in these forests.
  - **Animal Diversity:** Red-crowned cranes, owls, hawks, squirrels, sable, black bears, wolves, leopards, lynx, Siberian tigers, otters and red pandas are found in deciduous forests.
- **Adaptations:** Animals in this biome possess diverse adaptations to cope with the changing seasons:
  - **Migration:** Some birds and mammals, like cranes and wildebeests, migrate to escape harsh winters or dry seasons.

- **Hibernation:** Some mammals, like bears and bats, enter a state of lowered activity during winter to conserve energy.
- **Caching:** Squirrels and rodents stockpile food during abundant times to survive the lean season.
- **Water conservation:** Animals minimize water loss through reduced activity, efficient kidneys, and water-storing adaptations.

❑ **Other Features:**

- **Fire:** Sub-tropical deciduous forests are often adapted to fire regimes, with some species even relying on fire for seed germination and clearing competition.
- **Human impact:** This biome faces threats like deforestation, habitat loss and invasive species, necessitating conservation efforts.

Steppe or Temperate Grassland Biome

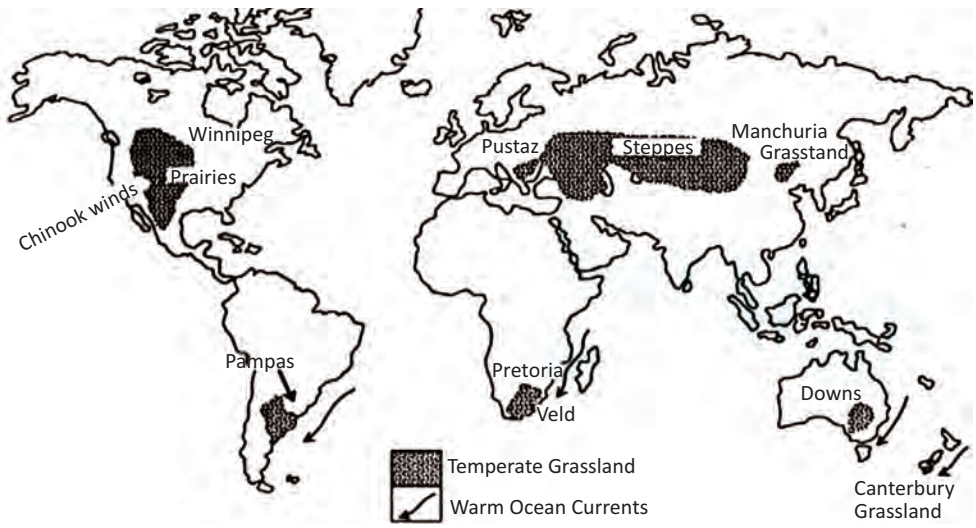


Fig. 2.14: Steppe or Temperate Grassland Biome

A steppe is a **dry, grassy plain.** Steppes occur in temperate climates, which lie **between the tropics and polar regions.** Temperate regions have distinct seasonal temperature changes, with cold winters and warm summers. Steppes are semi-arid, meaning they **receive 25 to 50 centimeters (10-20 inches) of rain each year.**

❑ **Geographical Extent:** They occur on several continents, with the largest and most well-known steppe being the **Eurasian Steppe, stretching from Hungary to China.** Other notable steppes include:

- North American Great Plains
- Patagonian Steppe (South America)
- New Zealand Tussock Grasslands

❑ **Flora Characteristics:**

- **Dominant vegetation:** Short grasses, typically less than 0.5 meters tall, adapted to arid conditions. Examples include feather grasses, fescues and needlegrasses.
- **Limited trees:** Due to low rainfall, trees are scarce except near rivers and streams. Some shrubby vegetation may be present.
- **Seasonal variation:** Spring rains lead to a brief flowering period with diverse wildflowers. Winter brings dry conditions and brown landscapes.

❑ **Fauna Characteristics:**

- **Water Conservation:** Many animals have small bodies and thick fur or feathers to minimize water loss through sweat and evaporation.
- **Nocturnal Activity:** With scorching day-time temperatures, many animals are most active at night when it is cooler. This nocturnal lifestyle helps them conserve water and avoid predators active during the day.
- **Burrowing:** Some animals, like badgers, prairie dogs, and ground squirrels, create burrows for shelter, escaping the heat, raising young
- **Key Species Examples:** Snakes, lizards, Grasshoppers, Beetles, etc.

❑ **Adaptations:**

- **Plants:** Deep root systems to access water, drought-resistant leaves and efficient nutrient cycling.
- **Animals:** Seasonal migrations, water-conserving adaptations (e.g., nocturnal activity), and efficient grazing strategies.

❑ **Other Features:**

- **Fire:** Natural fires periodically sweep through steppes, clearing dead vegetation and stimulating new growth.
- **Human impact:** Grazing, agricultural activities and development can threaten steppe ecosystems and their biodiversity. Conservation efforts are crucial.

IGNITE YOUR MIND

The Silent Symphony of the Grasslands: Where the Wind Whispers Through Swaying Grasses

Step into the boundless expanse of the grasslands, a world painted in golden hues, where the wind whispers secrets through swaying grasses. Beneath this seemingly simple landscape lies a hidden symphony of life, from the intricate dance of grazing herds to the silent hunters lurking in the tall grass. Explore the wonders that unfold in this vast ecosystem, understanding how each element plays a crucial role in maintaining the delicate balance of life.

Overall List of Grasslands in the World

Type	Geographic Distribution	Features	Economic Significance
Savannahs	Africa, South America, Australia	Combination of grass species with scattered trees, have economic significance	Livestock grazing, eco-tourism, conservation of biodiversity
Steppes	Eurasia	Extensive, flat terrain with semi-arid conditions	Livestock grazing, agricultural activities
Pampas	South America	Fertile land with moderate rainfall	Cattle ranching, farming
Prairies	North America	Rich soil with diverse precipitation	Agriculture, animal husbandry
Veld	Southern Africa	Various grass species with fluctuating rainfall	Livestock farming, agriculture
Downs	Australia, New Zealand	Undulating landscapes primarily covered in grass	Grazing, agricultural practices
Campos	South America	Seasons of wetness and dryness, mix of shrubs and grasses	Livestock grazing, farming
Pustaz Grasslands	Eurasia	Semi-arid with a variety of grasses and herbs	Grazing, conservation efforts
Mongolian-Manchurian grasslands	China, Russia, Mongolia	Cold climate, combination of grass and shrub species	Livestock grazing, traditional land management

Types of Grasslands in India

According to the climatic conditions, **six varieties of grasslands are distributed across various regions** of the Indian subcontinent. This discussion **focuses on four primary types of grasslands.**

- **Semi-arid Zone:**
  - **Geographical Coverage:** Encompasses the northern regions of Gujarat, Rajasthan (excluding the Aravallis), western Uttar Pradesh, Delhi, and Punjab.
  - **Terrain Description:** Characterized by broken topography, featuring hill spurs and sand dunes.
- **Dry Sub-Humid Zone:**
  - **Geographical Coverage:** Spans across the entirety of peninsular India, excluding the Nilgiri region.
- **Moist Sub-Humid Zone:**
  - **Geographical Coverage:** Extends over the Ganga alluvial plain in Northern India.
  - **Topographical Features:** Terrain is predominantly level, low-lying and poorly drained.
- **Humid Montane Regions:**
  - **Geographical Coverage:** Encompasses humid montane areas and moist sub-humid regions in Assam, Manipur, West Bengal, Uttar Pradesh, Punjab, Himachal Pradesh and Jammu and Kashmir.
  - **Formation Description:** Savannas in these regions originate from humid forests due to shifting cultivation practices and sheep grazing.

IGNITE YOUR MIND

Savannah Symphony: A Tapestry Woven from Grass and Woodlands

Picture yourself on the savanna, a breathtaking canvas where grasslands meet woodlands. Witness the graceful movements of zebras and wildebeests grazing under the watchful gaze of lions. What unique factors shape this diverse ecosystem, and how do the various inhabitants, from the smallest insects to the largest predators, interact to maintain a harmonious balance?

Taiga or Boreal Biome

The taiga, also known as the **boreal forest,** is the **world's largest terrestrial biome,** encompassing about 17% of Earth's land surface. Spanning the **northern latitudes between roughly 50° and 70° North,** it forms a circumpolar belt across North America, Europe, and Asia.

- **Geographical Extent:**
  - Covers vast stretches of **Canada, Alaska, Scandinavia, and Siberia.**

- Extends from **Iceland in the west to the Kamchatka Peninsula in the east.**
- Transitions to **tundra** in the north and temperate forests in the south.

❑ **Flora Characteristics:**

- Dominated by **coniferous trees** like spruce, pine, fir and larch.
- Trees are **needle-leaved** and **evergreen,** adapting to long, cold winters.
- Understory vegetation **includes mosses, lichens, shrubs, and wildflowers.**
- **Short growing season** due to harsh winters limits tree size and diversity.
- **Permafrost** (permanently frozen soil) underlies much of the biome, impacting plant growth.

❑ **Fauna:**

- **Fur:** Animals in the taiga often have thick fur or feathers to keep them warm.

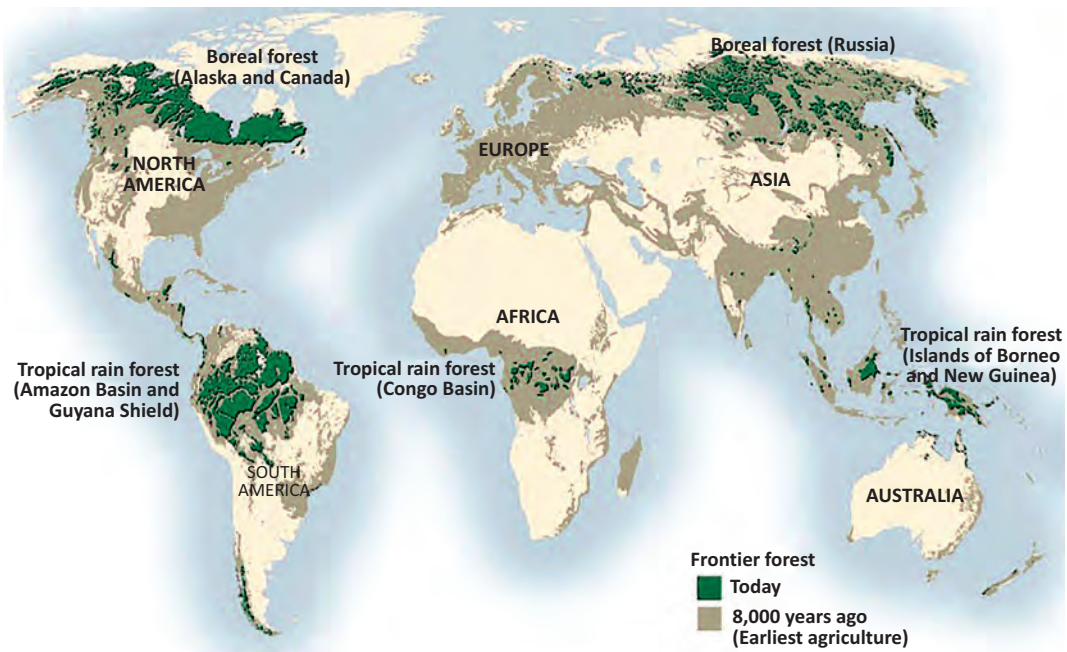


Fig 2.15: Extent of Taiga/Boreal Biome

- **Claws:** Many animals have sharp claws and are good at climbing trees.
- **Feet:** Animals have large feet to allow them to walk on the snow without sinking.
- **Fur color:** Mammals in the taiga often have white fur, or a white winter coat, in order to blend in with the snowy environment.
- **Examples:**
  - ❒ **Mammals:** Moose, reindeer, caribou, wolves, bears (brown, black), lynx, wolverine, squirrels, hares, lemmings.
  - ❒ **Birds:** Owls, hawks, eagles, woodpeckers, ptarmigan, warblers, songbirds.

❑ **Adaptations:**

- **Coniferous trees:** Needle leaves reduce surface area for snow accumulation and prevent water loss.
- **Animals:** Thick fur for insulation, hibernation during winter, migration to warmer regions.
- **Short growing season:** Plants focus on rapid growth and reproduction during the brief summer.
- **Food storage:** Animals store food during summer for winter survival.

❑ **Other Features:**

- **Taiga is vital for carbon storage** and plays a crucial role in mitigating climate change.
- **Human activities** like logging, mining, and oil and gas extraction pose threats to the taiga.
- **Conservation efforts** are crucial for protecting this unique and ecologically important biome.

Tundra Biome

The frozen expanses of the far North, known as the tundra, earned their name from the Finnish term **"tunturia," signifying treeless land.** This biome, often dubbed the **"ice desert" or "frozen prairie,"** stands as the chilliest among terrestrial ecosystems, characterized by its stark and unpredictable conditions.

Despite its harsh environment, the tundra teems with a remarkable array of flora and fauna, showcasing nature's resilience and harsh allure.

❑ **Geographical Extent:** Found in two main types:

- **Arctic Tundra:** Stretching across the **Northern hemisphere** of the Earth, the Arctic tundra encompasses regions encircling the North Pole, extending southwards to the evergreen forests of the boreal biomes.

- **Alpine Tundra:** The Alpine biome typically sits just beneath the snow line of mountains, commonly at altitudes exceeding 10,000 feet. The Alpine Tundra biome closely resembles the Arctic Tundra, distinguished primarily by the absence of trees.

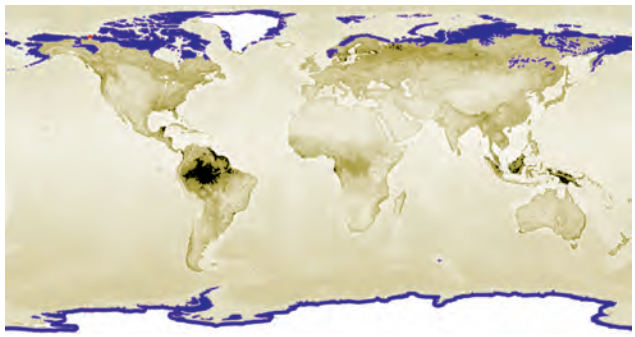


Fig 2.16: World Distribution of Arctic Tundra Biome

Characteristic

- **Climate:** The tundra experiences long, harsh winters and brief, cool summers with minimal precipitation, mainly in the form of snow.
- **Flora:** The vegetation comprises mosses, lichens, sedges, dwarf heath, willows, and birches.
- **Fauna:** Various animals inhabit the tundra, including arctic foxes, polar bears, caribou, musk oxen, and a variety of migratory birds.
- **Other Features:** Distinctive aspects of the tundra include permafrost soil, low biodiversity, and animals with specialized adaptations to endure extreme cold conditions.

Fig. 2.17 : Extent of Alpine Tundra Biome

IGNITE YOUR MIND

The Silent Sentinels: Mountain Majesty and Ecological Significance

Towering mountains pierce the clouds, their slopes harboring unique ecosystems that thrive in diverse microclimates. Explore how these majestic landforms influence the climate, vegetation, and animal life around them, acting as silent sentinels that shape the very fabric of our planet.

Major Biomes of The World

Biome	Climate	Dominant Vegetation	Notable Animals	General Soil Type	Locations
Tundra Biome	Cold and dry	Mosses, lichens, some shrubs	Arctic foxes, musk oxen, caribou	Permafrost (frozen ground)	Arctic and Alpine Tundra Biome
Desert Biome	Hot and dry	Cacti, succulents	Camels, scorpions, snakes	Sandy and nutrient-poor	Tropical and Mid-Latitude Desert Biome
Savanna Biome	Warm, distinct wet/dry	Grasslands, scattered trees/ shrubs	Lions, zebras, giraffes, elephants	Nutrient-poor with organic matter	Tropical Wet and Dry Biome (Savanna)
Mountain Biome	Varies with altitude	Forests, alpine meadows, tundra	Diverse range of adapted species	Varies with altitude	Mountainous regions
Grassland Biome	Temperate	Grasses, few trees/ shrubs	Bison, pronghorn, rodents	Deep and fertile	Steppe or Temperate Grassland Biome
Rainforest Biome	Warm and wet	Dense evergreen forests	Jaguars, toucans, monkeys	Nutrient-poor but rapid recycling	Tropical Rainforest Biome
Polar Regions Biome	Extremely cold	Limited vegetation, ice/snow cover	Species adapted to extreme cold	Frozen or covered with ice	Arctic and Antarctic Polar regions
Tropical Deciduous Biome	Warm, distinct wet/dry	Deciduous trees, shrubs	Elephants, tigers, primates, birds	Nutrient-rich but erosion-prone	Tropical Deciduous Biome (Monsoon Climate)
Taiga (Boreal Forest) Biome	Cold, sub-arctic	Evergreen coniferous forests	Moose, wolves, bears	Acidic and nutrient-poor	Taiga or Boreal Biome

Northern Coniferous Forest Biome	Cold, sub-arctic	Coniferous forests	Moose, wolves, bears	Acidic and nutrient-poor	Northern regions with coniferous forests
Mediterranean Scrub Forest	Warm, distinct wet/dry	Drought-resistant shrubs, small trees	Various animals adapted to dryness	Varies with location and topography	Sub-Tropical Deciduous Biome in Mediterranean Climate
Temperate Deciduous Forest	Moderate temperature	Deciduous trees	Deer, squirrels, raccoons	Rich and fertile	Temperate Deciduous Biome in North Western Europe

FOREST ECOSYSTEM

A forest ecosystem denotes the terrestrial environment where trees, insects, animals, and humans coexist. It's a component of the larger ecosystem, the planet's most extensive functional unit, comprising all geographical features and life forms.

The arrangement and abundance of trees within forest vegetation are influenced by soil type, climate, and local topography. These forest biomes typically follow a gradient from north to south latitude or from high to low altitude. **Here are the primary classifications:**

Global Classification of Forest Ecosystem

Ecosystem Type	Characteristics	Flora and Fauna	Soil Characteristics
Coniferous Forest (Boreal Forest)	Found in cold regions with high rainfall and strong seasonal climates.	Dominated by evergreen species like spruce, fir, and pine trees.	Thin podzolic soils, poor in nutrients due to slow weathering and decomposition.
Temperate Deciduous Forest	Moderate climate with deciduous trees shedding leaves in fall and regrowing in spring.	Various deciduous tree species.	Podzolic soils, fairly deep, with uniform precipitation.
Temperate Evergreen Forest	Mediterranean climate with warm, dry summers and cool, moist winters.	Low broad-leaved evergreen trees.	Adapted to regenerate quickly after fires.
Temperate Rain Forests	Marked seasonality in temperature and rainfall, with heavy fog contributing to water sources.	High biotic diversity compared to other temperate forests.	Red latosols, thick and poor in nutrients, with high leaching rates.
Tropical Rainforests	Occur near the equator with uniform high temperatures and humidity.	Highly diverse vegetation with tall trees, vines, epiphytes, and shrubs.	Vertically stratified ecosystem with red latosols, thick and poor in nutrients.
Tropical Seasonal Forests	Found in regions with pronounced wet and dry periods.	High total annual rainfall but segregated into wet and dry seasons.	Share similarities with tropical rainforests in flora and fauna.
Subtropical Rainforests	Found in regions with high rainfall and minimal temperature differences between winter and summer.	Broad-leaved evergreens and common epiphytes.	Similar to tropical rainforests in soil characteristics and biodiversity.

Indian Forests Types

India boasts a diverse range of forests, with the country's **total forest and tree cover now accounting for 24.62%** of its total geographical area. Among the prominent types of forests found in India are coniferous forests, evergreen forests, wet evergreen forests, deciduous forests, broad-leaved forests, and mangrove forests.

- In India, there is currently **no official national definition of 'forest.'** The responsibility for defining forests lies with individual states.
- The Supreme Court ruling in the **T.N. Godavarman Thirumulkpad vs the Union of India case** in 1996 affirmed the states' authority to define forests.
- According to the Supreme Court, the term "forest" should be interpreted based on its dictionary definition. This interpretation applies uniformly to all legally acknowledged forests, irrespective of their classification as reserved, protected, or otherwise.

Classification of Forests

Indian forests are categorized into **sixteen types** according to the classification system developed by Champion and Seth, based on India's annual average rainfall.

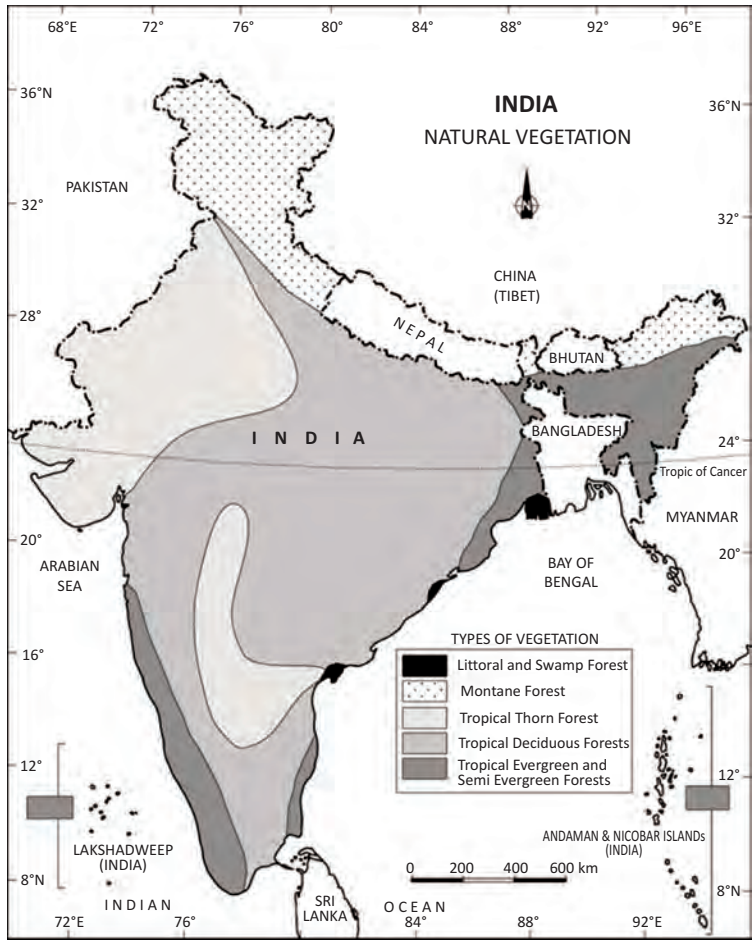


Fig. 2.18: Map showing Natural Vegetation of India

Forest Type	Location	Characteristics
Tropical Wet Evergreen Forests	Western Ghats, Nicobar and Andaman Islands, north-eastern region.	Tall, straight evergreen trees; Common trees include jackfruit, betel nut palm, jamun, mango, and hollock; Tier pattern with shrubs, short structured trees, and tall trees; Ferns and various orchids grow on tree trunks.
Tropical Semi-evergreen Forests	Western Ghats, Andaman and Nicobar Islands, Eastern Himalayas.	Mixture of wet evergreen and moist deciduous trees; Dense forest with a variety of both tree types.
Tropical Moist Deciduous Forests	Throughout India except western and north-western regions.	Tall trees with broad trunks and branching roots; Some trees shed leaves in dry season; Layer of shorter trees and evergreen shrubs in undergrowth; Dominated by sal and teak, with mango, bamboo, and rosewood.
Littoral and Swamp Forests	Andaman and Nicobar Islands, Ganga and Brahmaputra delta areas.	Soft tissue roots for breathing in water.
Tropical Dry Deciduous Forests	Northern India (except North-East), Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu.	Canopy height usually under 25 meters; Common trees include sal, various acacias and bamboo.
Tropical Thorn Forests	Areas with black soil: North, West, Central, and South India.	Trees limited to 10 meters; Typical plants include spurge, caper, and cactus
Tropical Dry Evergreen Forests	Tamil Nadu, Andhra Pradesh, Karnataka coast.	Mainly hard-leaved evergreen trees with fragrant flowers; Few deciduous trees present.
Subtropical Broad-leaved Forests	Eastern Himalayas, Western Ghats (Silent Valley).	Varied vegetation; Predominant species include poonspar, cinnamon, rhododendron, and fragrant grass (Silent Valley); Affected by shifting cultivation and forest fires (Eastern Himalayas); Mainly evergreen trees with some deciduous; Oak, alder, chestnut, birch, cherry trees; Orchids, bamboo, and creepers are abundant.

Forest Type	Location	Characteristics
Subtropical Pine Forests	Shivalik Hills, Western and Central Himalayas, Khasi, Naga, Manipur Hills.	Predominantly chir, oak, rhododendron, pine, Sal, amla laburnum in lower regions.
Subtropical Dry Evergreen Forests	Shivalik Hills, Himalayan foothills (up to 1000 metres).	Prolonged hot and dry season with cold winter; Mainly evergreen trees with shining, varnished leaves.
Montane Wet Temperate Forests	Eastern Nepal to Arunachal Pradesh (North), Nilgiri Hills, higher Kerala regions (South).	Different layers with coniferous, deciduous, and ground flora; Denser in North; Abundance of rhododendrons and ground flora.
Himalayan Moist Temperate Forests	Western to Eastern Himalayas.	Broad-leaved trees (western) and lush, dense vegetation (eastern); Variety of trees including oak, walnut, rhododendron; Conifers and bamboo present; Affected by heavy rainfall
Himalayan Dry Temperate Forests	Lahul, Kinnaur, Sikkim, other Himalayan parts.	Coniferous dominance with oak, maple, ash Fir, juniper, deodar at higher elevations.
Subalpine Forests	Kashmir to Arunachal Pradesh (2900 to 3500 metres).	Vegetation varies by region with juniper, rhododendron, willow, black currant (West); Red fir, black juniper, birch, larch (East); Higher timberline in East due to rainfall; Abundance of rhododendrons.
Moist Alpine Scrub	Along Himalayas, higher hills near Myanmar border.	Low scrub, dense evergreen forest with rhododendron, birch; Ground covered in mosses, ferns; Heavy snowfall.
Dry Alpine Scrub	3000 to 4900 metres altitude.	Predominantly dwarf plants like black juniper, drooping juniper, honeysuckle, willow.

Indian forests can be further classified on following basis:

❑ **On Administration Basis:**

- **Reserved Forests:** Under direct government supervision, no public entry for commercial cattle grazing. This category includes 53% of total forest area of the country.
- **Protected Forests:** Looked after by the government, local people allowed limited forest produce collection and cattle grazing. This category includes 29% of total forest area of the country.
- **Unprotected Forests:** No restrictions on tree cutting or grazing, this category includes 18% of the Total Forest Area of the country.

❑ **As per Constitution of India:**

- **State Forests:** Under government control, cover 94% of TFA.
- **Commercial Forests:** Administered by local bodies, cover 5% of TFA.
- **Private Forests:** Under private ownership, cover slightly more than 1% of TFA.

❑ **Based on Composition:**

- **Coniferous Forests:** Temperate and subtropical monsoon forests, upper elevations of Eastern Middle Himalayas and N-E Indian states.
- **Broad-Leaf Forests:** Found in plateaus, plains, and mountains, cover 94% of TFA.

❑ **Forest Classification (As per ISFR 2021):**

- **Very Dense Forests:** Areas with a canopy cover of 70% and above.
- **Moderately Dense Forests:** Areas with a canopy cover between 40% and 70%.
- **Open Forests:** Areas with a canopy cover between 10% and 40%.
- **Scrub:** Areas with a canopy cover less than 10%, including degraded forests and open scrub.
- **Non-Forest:** Areas without any forest or tree cover.

Indian State of Forest Report, 2021

Since 1987, the Indian State of Forest Report (ISFR) has served as a biennial check-up for India's forests and tree resources. This comprehensive report, compiled by the Union Ministry of Environment, Forests and Climate Change (MoEFCC), was last released in 2021, offering crucial data and analysis on the state of India's vital green spaces.

❑ **Scope of Assessment (ISFR 2021)**

- Presents the latest data on forest cover and tree cover across India.
- Includes estimates on growing stock, extent of trees outside forests, mangrove cover, and bamboo resources.
- Also evaluates forest carbon stock.
- The chapter on forest carbon assessment also includes India's progress toward meeting its Nationally Determined Contribution commitments.

❑ **New Features of Report**

- The Indian State of Forest Report, 2021 includes a special chapter on "Forest Cover Assessment in Tiger Reserves and Tiger Corridor Areas of the Country and Decadal Change in Forest Cover," alongside standard chapters.
- It presents findings from two special studies: Above **Ground Biomass Estimation Using Synthetic Aperture Radar Data** (in partnership with ISRO) and **Climate Hot Spots in Forest Areas Studies.**
- For the first time, the report assesses forest cover in tiger reserves, tiger corridors, and the Gir forest, home to the Asiatic lion.

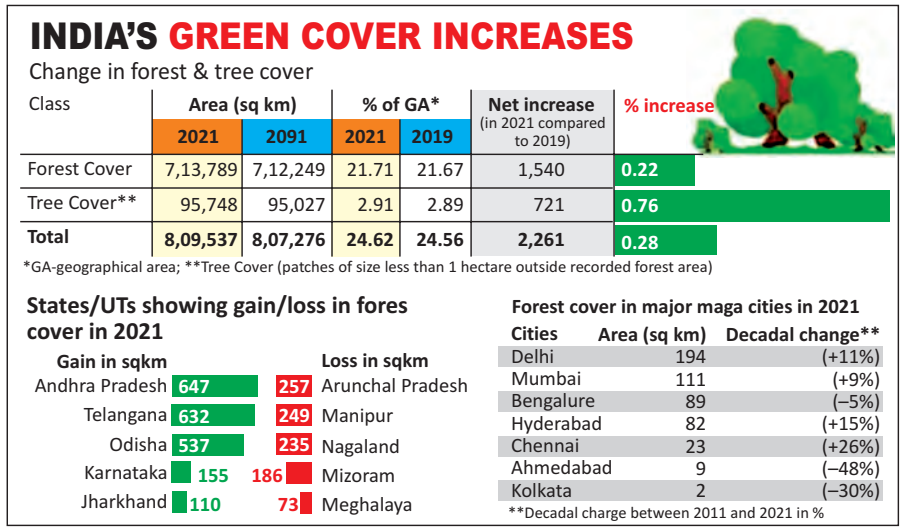


Fig 2.19: Key Findings of the Report

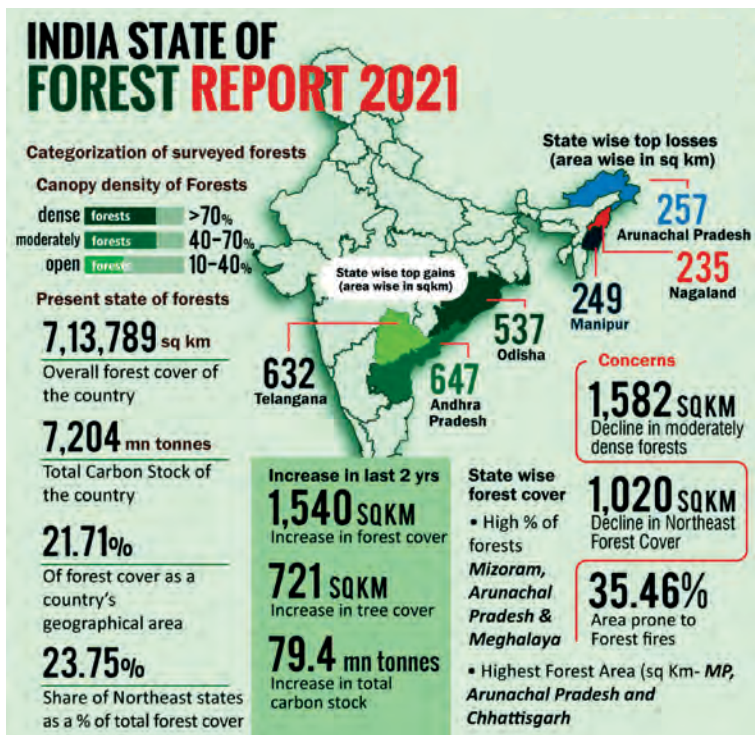

INDIA STATE OF FOREST REPORT 2021
Categorization of surveyed forests
Canopy density of Forests
dense forests >70%
moderately forests 40-70%
open forests 10-40%
Present state of forests
7,13,789 sq km
Overall forest cover of the country
7,204 mn tonnes
Total Carbon Stock of the country
21.71%
Of forest cover as a country's geographical area
23.75%
Share of Northeast states as a % of total forest cover
State wise top losses (area wise in sq km)
257 Arunachal Pradesh
235 Nagaland
249 Manipur
537 Odisha
State wise top gains (area wise in sqkm)
632 Telangana
647 Andhra Pradesh
Increase in last 2 yrs
1,540 SQKM
Increase in forest cover
721 SQKM
Increase in tree cover
79.4 mn tonnes
Increase in total carbon stock
State wise forest cover
• High % of forests Mizoram, Arunachal Pradesh & Meghalaya
• Highest Forest Area (sq Km- MP, Arunachal Pradesh and Chhattisgarh
Concerns
1,582 SQKM
Decline in moderately dense forests
1,020 SQKM
Decline in Northeast Forest Cover
35.46%
Area prone to Forest fires

Fig 2.20: India State of Forest Report 2021

Important Terms Related to Forests (ISFR 2021)

- **Forest Area:** Total geographical expanse managed or administered as forests, encompassing both actual forest cover and non-forest land within recorded forest areas.
- **Forest Cover:** The actual forested area where tree canopy covers a certain percentage of the ground, typically areas with tree canopy density more than 10%.
- **Tree Cover:** The area covered by the vertical projection of the tree canopy, expressed as a percentage of the total ground area.
- **Canopy Density:** The degree of closure provided by the tree canopy, expressed as a percentage, reflecting the proportion of the ground covered by the vertical projection of the canopy.
- **Open Forests:** Areas with moderate tree density, where canopy cover is between 10% and 40%.
- **Under Canopy Cover:** Areas with less than 10% tree cover but more than 1% tree cover.
- **Degraded Forest:** Forest areas that have undergone deterioration in terms of biodiversity and ecosystem services.
- **Water Bodies within Forest:** Include rivers, lakes, and other water bodies located within forest areas.

Key Findings from ISFR 2021 Assessment

- **Total Forest and Tree Cover: 24.62% (80.9 M Ha)** of the country's area.
  - Forest cover: 7,13,789 sq km (21.71%).
  - Tree cover: 2.91%.
- **Comparative Analysis:** Overall increase of **0.28%**, with forest cover up by **0.22%** and tree cover by **0.76%** compared to ISFR 2019.
- **Forest Cover in Hill and Tribal Districts:** Hill districts - **40.17%,** slight decrease; Tribal districts - **37.53%**.
- **Change in Recorded Forest Area/Green Wash (RFA/GW):** Increase by 31 sq km within RFA/GW, substantial increase outside by **1,509 sq km**.
- **Forest Cover in Indian States/UTs:**
  - **Highest Forest Cover Area:** Madhya Pradesh **(77,493 sq km),** Arunachal Pradesh **(66,431 sq km),** Chhattisgarh **(55,717 sq km),** Odisha **(52,156 sq km),** Maharashtra **(50,798 sq km)**.
  - **Highest Forest Cover Percentage:** Lakshadweep (90.33%), Mizoram (84.53%), Andaman and Nicobar Islands (81.75%), Arunachal Pradesh (79.33%), Meghalaya (76.00%).
  - **States/UTs with Less Than 10% Forest Cover:** Ladakh **(1.35%),** Haryana **(3.63%),** Punjab **(3.67%),** Rajasthan **(4.87%),** Uttar Pradesh **(6.15%),** Gujarat **(7.61%),** Bihar **(7.84%)**.
  - **States/UTs with Considerable Forest Cover Increase (2019-2021):** Andhra Pradesh **(+647 sq km),** Telangana **(+632 sq km),** Odisha **(+537 sq km)**.
  - **Top 5 States with Most Mangrove Forest Cover:** West Bengal **(2,114 sq km),** Gujarat **(1,175 sq km),** Andaman & Nicobar Islands **(616 sq km),** Andhra Pradesh **(405 sq km),** Maharashtra **(324 sq km),** Odisha **(259 sq km)**.
  - **Forest Cover in North-Eastern Region:** Decrease by **1,020 sq km (0.60%)**.
- **Mangrove Cover Increase:** Total mangrove cover - **4,992 sq km**. Odisha **(8 sq km),** Maharashtra **(4 sq km),** and Karnataka show the highest increase in mangrove cover **(3 sq km each)**.
- **Total Carbon Stock:** Projected at **7,204** million tonnes with an annual rise of **39.7 million tonnes**. Increase of **79.4 million tonnes** since 2019.
- **Bamboo Forests:** Growth from **13,882 million culms** in 2019 to **53,336 million culms** in 2021.

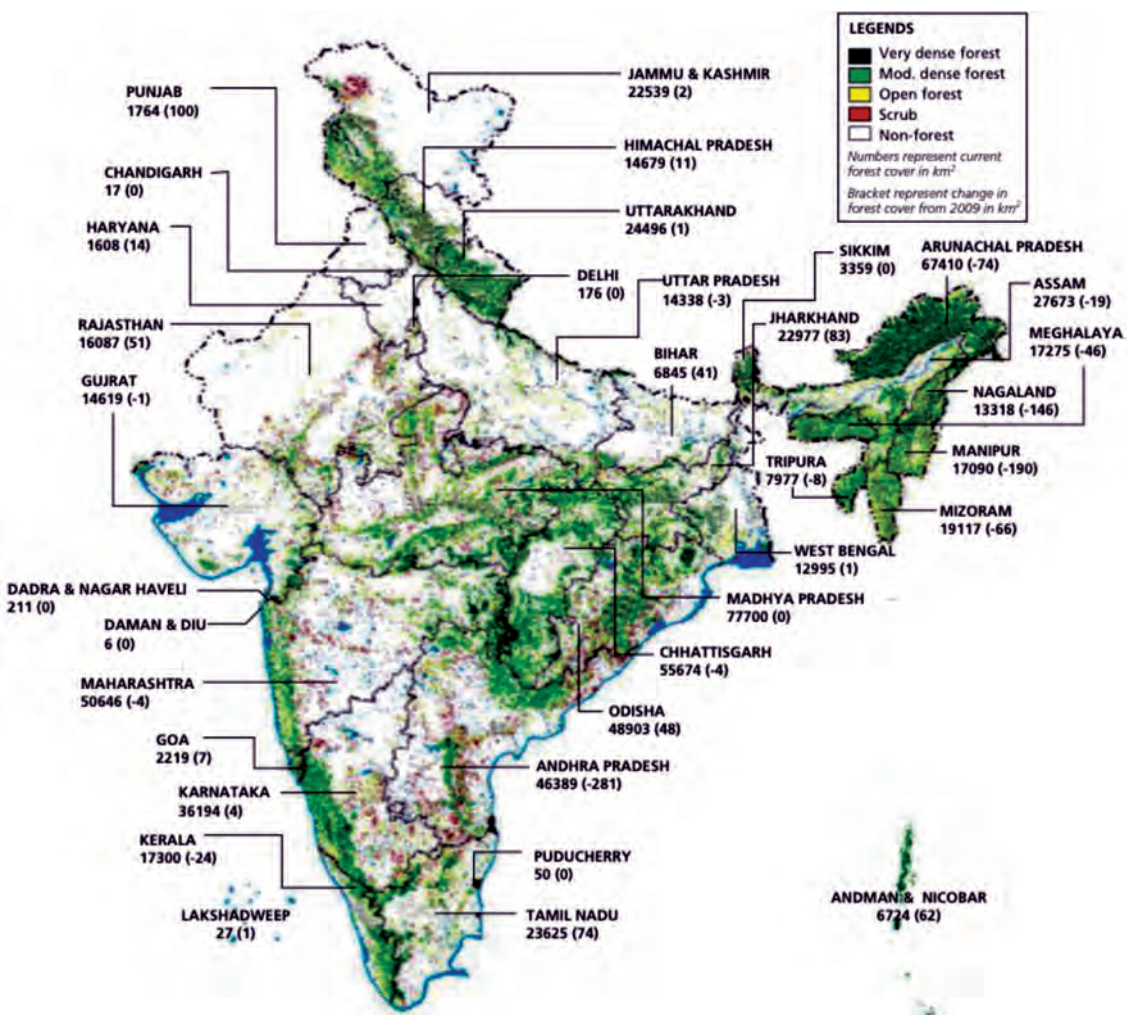


Fig. 2.21: India's Forest Cover- by States and Union Territories

- **Forest Fires in India:**
  - **ISFR 2021:** Forest fires threaten **35.46%** of India's forest cover.
  - **Climate Change Hotspots: 45-64%** of Indian forests affected by rising temperatures by **2030**. Except Assam, Meghalaya, Tripura, and Nagaland.
  - **Ladakh Vulnerability:** Ladakh's forest cover **(0.1-0.2%)** particularly susceptible to climate change.

Significance of Forest Ecosystem

- **Sustaining Life:** Vital for air, food, and materials like paper and wood.
- **Environmental Balance:** Maintains natural equilibrium and acts as carbon sinks.
- **Air Purification:** Filters pollutants and releases oxygen.
- **Microclimate Regulation:** Modulates temperature and humidity.
- **Contribution to Precipitation:** Indirectly aids precipitation formation.
- **Flood Prevention:** Absorbs excess water and prevents soil erosion.
- **Soil Conservation:** Anchors soil and prevents erosion.
- **Medicinal Resources:** Source of medicinal plants and herbs.
- **Sustainable Resource Provision:** Provides fuelwood, timber, and raw materials for various industries.

Challenges

- **Loss of Forest Cover:** Second globally, driven by infrastructure development, agriculture expansion, and extraction.
- **Biodiversity Loss:** Threatens numerous species, including endangered animals.
- **Agriculture Expansion:** Encroachment reduces forest cover.
- **Forest Fires:** Increasingly frequent and intense fires due to human activities and climate change.
- **Climate Change:** Rising temperatures and extreme weather events stress forests, making them more vulnerable.

Deforestation

The uncontrolled cutting down of trees due to **urban expansion, industrial growth, mining activities,** and wood consumption for various domestic and commercial needs has led to significant depletion of forest resources.

Current Status

- According to Our World in Data, the **world loses around 10 million hectares of forest each year,** which is the size of Portugal. However, about half of this deforestation is **offset by regrowing forests,** so overall, the world loses around 5 million hectares each year.
- The **rate of deforestation** has declined substantially since 1990, when an estimated 420 million hectares of forest have been lost worldwide. In 2015–2020, the annual rate of deforestation was estimated at 10 million hectares, down from 12 million hectares in 2010–2015. In 2022, tropical primary forest loss totaled 4.1 million hectares, the equivalent of losing 11 football fields of forest per minute.

Causes

- **Shifting Cultivation:**
  - **Traditional Practice:** It involves clearing a portion of land, burning the vegetation, and mixing the resulting ash with soil to enrich it with nutrients.
  - **Crop Rotation:** The cleared land is used for cultivating crops for a short period, typically two to three years, with moderate yields.
  - **Land Rotation:** After cultivation, the land is left fallow to regain fertility, while the process repeats on a new plot elsewhere.
- **Development Projects:**
  - **Population Growth Impact:** The burgeoning human population's needs have surged, necessitating development projects.
  - **Environmental Impact:** Projects such as hydroelectric ventures, large dams and infrastructure construction, though beneficial, pose environmental challenges.
  - **Deforestation Requirement:** Many projects entail extensive deforestation.
- **Fuel Requirements:** Increasing Demand and growing populations lead to higher demand for firewood, escalating pressure on forests and deforestation rates.
- **Raw Material Needs:**
  - **Industrial Usage:** Wood serves as a crucial raw material in paper, furniture and various other industries.
  - **Diverse Industry Needs:** Industries rely on plants for numerous raw materials like drugs, scents, resins and rubber, exacerbating pressure on forest ecosystems.
- **Other Contributing Factors:**
  - **Overgrazing, Agriculture, Mining:** Activities such as overgrazing, agriculture expansion and mining also contribute to deforestation.
  - **Urbanization and Infrastructure:** Urbanization, flood, fire, pests, diseases and defense and communication initiatives further accelerate deforestation.

Consequences of Deforestation

- **Impact on Forests:**
  - **Decline in Closed Forests:** Deforestation has led to the reduction of closed forests, resulting in an increase in degraded forest areas.
  - **Disruption of Moisture Recycling:** Forests typically recycle moisture through transpiration, contributing to local precipitation. Deforestation disrupts this cycle, leading to reduced rainfall.

- **Groundwater Depletion:** Deforestation causes an immediate drop in groundwater levels and long-term reduction in precipitation, as the natural moisture cycle is disturbed.
- **Increased Runoff:** With deforestation, the natural water reuse cycle breaks down, leading to rapid runoff and loss of water.

❑ **Mining Impact on Deforestation:**
- **Forest Degradation:** Much of India's mining activity occurs in forested regions, leading to deforestation and soil erosion.
- **Underground Mining Effects:** Underground mining contributes to forest denudation as timber is utilized to support mine galleries' roofs.
- **Abandoned Mines' Consequences:** Abandoned mines often suffer from extensive gully erosion, further degrading habitats and ecosystems.

❑ **Overall Environmental Consequences:**
- **Biota and Ecosystem Impact:** Deforestation adversely affects biodiversity and neighboring ecosystems.
- **Soil Erosion:** Deforestation exacerbates soil erosion and land degradation.
- **Alteration of Groundwater Channels:** Deforestation alters natural groundwater channels.
- **Pollution and Scarce Resources:** Deforestation contributes to pollution and scarcity of resources.

IGNITE YOUR MIND

The Silent Scourge: Deforestation - A Looming Threat
Imagine a world stripped bare, its once vibrant forests reduced to mere memories. Explore the driving forces behind deforestation, uncovering the economic and social factors that contribute to this silent scourge. Unmask the cascading ecological and societal consequences of this alarming trend, and ignite a conversation about sustainable practices for protecting our precious forests.

Major Forest Conservation Initiatives

Global

❑ **UN Decade on Ecosystem Restoration:** A global initiative that aims to prevent, halt and reverse the degradation of ecosystems on every continent and in every ocean, by 2030.

❑ **Convention on Biological Diversity:** It promotes conservation and sustainable use of biodiversity, including forests, through various programmes and initiatives.

❑ **Reducing Emissions from Deforestation and Forest Degradation (REDD+):** REDD+ offers financial incentives to developing countries for reducing deforestation and forest degradation, promoting conservation and sustainable management.

❑ **Bonn Challenge:** Aims to restore 350 million hectares of degraded land by 2030, focusing on enhancing biodiversity, ecosystem services, and climate resilience.

❑ **Forest Landscape Restoration:** It restores ecological integrity, socio-economic benefit and climate resilience of degraded forest landscapes through holistic and participatory approaches.

❑ **Miyawaki Method:** The Miyawaki Method is a dense and diverse afforestation technique developed by Japanese botanist Akira Miyawaki, emphasizing native plant species and dense planting to accelerate forest growth, enhance biodiversity and mitigate climate change impacts through rapid reforestation in small urban spaces.

❑ **The New York Declaration on Forests** is a voluntary and non-legally binding political declaration which grew out of dialogue among governments, companies and civil society, spurred by the UN Climate Summit in 2014.

❑ **The BioCarbon Fund Initiative for Sustainable Forest Landscapes (ISFL)** is a multilateral fund, supported by donor governments and managed by the World Bank. It promotes reducing greenhouse gas emissions from the land sector, including efforts to reduce deforestation and forest degradation in developing countries (REDD+), sustainable agriculture, as well as smarter land-use planning, policies and practices.

❑ **The Forest Carbon Partnership Facility** is a global partnership of governments, businesses, civil society, and Indigenous Peoples focused on reducing emissions from deforestation and forest degradation, forest carbon stock conservation, the sustainable management of forests, and the enhancement of forest carbon stocks in developing countries (activities commonly referred to as REDD+). The four strategic objectives of the FCPF:
- To assist countries in their REDD+ efforts by providing them with financial and technical assistance in building their capacity to benefit from possible future systems of positive incentives for REDD+.
- To pilot a performance-based payment system for REDD+ activities, with a view to ensure equitable benefit sharing and promoting future large-scale positive incentives for REDD+.
- To test ways to sustain or enhance livelihoods of local communities and to conserve biodiversity, within the approach of REDD+.
- To disseminate broadly the knowledge gained in the development of the Facility and the implementation of Readiness Preparation Proposals (RPPs) and Emission Reductions Programs (ERPs).

India

- **Forest Survey of India (FSI),** based in Dehradun, conducts biennial assessments of forest cover since 1987, with findings published in the India State of Forest Report (ISFR).
- **Government initiatives aim to enhance forest cover:**
  - **Green India Mission (GIM)** since 2015-16 focuses on afforestation, with Rs. 755.28 Crores disbursed to 17 States and one Union territory. It is one of the eight missions under the National Action Plan on Climate Change (NAPCC). Its objective is to respond to climate change by a combination of adaptation and mitigation measures. It is aimed at protecting, restoring, and enhancing India's diminishing forest cover.
  - National Afforestation Programme merged with GIM, targeting forest regeneration.
  - **Nagar Van Yojana (NVY)** launched in 2020 aims to establish 600 Nagar Vans and 400 Nagar Vatika in urban areas by 2024-25.
  - **Compensatory Afforestation Fund (CAMPA)** aids states in afforestation, with 90% funds allocated to states and 10% retained by the Centre.
  - Hyderabad has been recognised in 2020 as Tree City of the World by the Arbor Day Foundation and the Food and Agriculture Organization (FAO). It was given for its commitment to growing and maintaining urban forests.
- **Government Initiatives to Protect Forest Ecosystem**
  - **Botanical Survey of India (BSI) and Zoological Survey of India (ZSI)** conduct surveys and inventories of floral and faunal resources.
  - The Forest Survey of India evaluates forest cover to establish an accurate database for planning and monitoring.
  - **Biological Diversity Act 2002 and Biological Diversity Rules 2004** focus on conserving the country's biological resources and regulating access for equitable benefit sharing.
  - Industries must acquire **"Consent for Establishment" and "Consent to Operate"** from State Pollution Control Boards (SPCBs) under the Water Act of 1974 and Air Act of 1981.
- **Multi-departmental efforts** involve line Ministries, State Governments/UT Administrations, NGOs, civil society, and corporates, supporting afforestation through schemes like Mahatma Gandhi National Rural Employment Guarantee Scheme, National Bamboo Mission, and Sub-Mission on Agro-forestry.

Further Steps Needed

- **India's National Forest Policy** has established fundamental principles for the effective management and preservation of the country's forest resources, which include:
  - **Categorizing forests** based on their functional roles into protected forests, reserved forests, village forests, etc.
  - **Expanding forest coverage** by planting trees to improve local environmental conditions.
  - Ensuring a sustainable increase in fodder and timber supplies for local communities.
  - Resisting the unchecked expansion of agricultural land at the expense of forests.
  - Implementing a **large-scale tree plantation initiative** to cover 33 percent of the country's geographical area with forests.
- **Strengthen Legal Framework:** Update and effectively implement forestry laws to address loopholes and ensure transparency.
- **Decentralize Management:** Empower local communities through Joint Forest Management (JFM) programmes, granting them greater control and benefits from sustainable forest management.
- **Encourage Agro-forestry:** Integrate trees into agricultural landscapes for increased income, soil health, and biodiversity.
- **Combat Invasive Species:** Develop and implement strategies to control and eradicate invasive plant and animal species.

Forests play a crucial role in maintaining Earth's climate stability due to their global impact through photosynthesis. Their significance cannot be overstated. From providing the oxygen we breathe to supplying timber, forests are vital for our survival. They safeguard watersheds, prevent soil erosion, mitigate climate change, and serve as habitats for wildlife while sustaining human livelihoods.

CONTEMPORARY ISSUES

Human-Modified Ecosystems

Human desires and requirements have significantly transformed and disrupted natural ecosystems, leading to substantial modifications.

Primary Reasons for Modification:

- **Rising Human Population:** The burgeoning human population exerts immense pressure on natural ecosystems, driving alterations to accommodate growing needs.
- **Escalating Human Needs:** Increasing demands for resources and amenities necessitate modifications to ecosystems to fulfill human requirements.
- **Shifts in Lifestyles:** Changing lifestyles, consumption patterns, and technological advancements contribute to the modification of natural ecosystems as humans adapt to new ways of living.

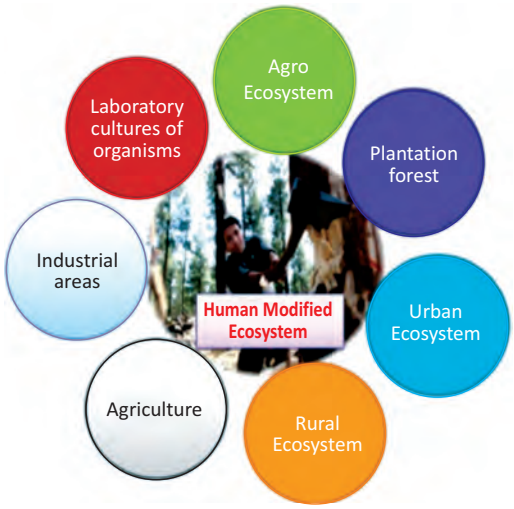


Fig. 2.22: Human Modified Ecosystem

- **Some examples of human modified ecosystems are:** (1) Agro-ecosystems; (2) Plantation forests; (3) Urban ecosystems; (4) Rural ecosystems; (5) Industrial areas and (6) Laboratory cultures

Agro-Ecosystems and Agricultural Practices

Agroecosystems represent expansive **regions dedicated to the cultivation of commercial crops.** These crops are planted and harvested by individuals for financial gain. **Alternatively labeled as crop ecosystems,** they are predominantly managed as monocultures, with a single crop species covering the entire expanse, although occasionally multiple crop species are cultivated simultaneously within the same field.

Characteristics of Agro-ecosystems

- These ecosystems are significantly simplified, mainly accommodating the cultivation of a single crop species.
- There is minimal species diversity within these ecosystems.
- They are notably unstable and lack self-sustainability.
- Prone to weed infestation and vulnerable to plant diseases.
- The soil quality is impoverished, lacking in essential nutrients, necessitating supplementation with chemicals or fertilizers.

Plantation Forest

This is a human-created ecosystem **comprising trees of a specific species.** These trees are planted in various locations, including barren land, privately owned land, village council land, roadsides, canal banks, along railway lines, and on land unsuitable for agriculture. The objective is to **cultivate rapidly growing trees that hold commercial value.**

Characteristics of Plantation Forests:

- Plantation forests typically consist of monocultures, such as oil palm, rubber and coffee plantations.
- Trees within plantation forests are typically of similar ages.
- Plantation forests are highly vulnerable to pathogens and pests.
- They exhibit low species diversity.
- Constant human attention and management is necessary.
- Recently, there has been a surge in the popularity of Jatropha curcas plantations for bio-diesel production.

Urban Ecosystems

Urban living entails residing in a densely populated city environment. Currently, there appears to be a global trend towards urbanization, **with people from various regions relocating to towns and cities.** In 1800, less than 10% of the global population resided in urban areas (equivalent to 50 million people), but by 1985, this figure had surged to 2 billion. Today around 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050.

Characteristics of Urban Ecosystems:

- Urban areas often face issues of congestion, housing shortages and the proliferation of slum areas.
- Cities rely increasingly on importing energy, food, and various materials from external sources to sustain themselves.
- Urban centers produce significant amounts of solid and liquid waste, as well as air pollutants, contributing to environmental pollution problems.
- Urban living offers more job opportunities, on the other hand, it also intensifies competition in the job market.
- Access to better educational facilities is a common feature of urban areas.
- Urban centres typically provide superior medical facilities and healthcare services.

Rural Ecosystems

Rural ecosystems represent an **intermediate stage between natural and urban environments,** characterized by a comparatively lower degree of human exploitation of nature and natural resources. Residents of rural areas typically maintain a **closer connection to nature and tend to lead simpler lifestyles.**

Characteristics of Rural Ecosystems:

- Several villages are under the ownership of a single family.
- Rural dwellers typically reside in small groups within thatched or mud houses nestled amid farmlands. Their livelihoods are predominantly linked to agriculture, relying on locally sourced resources.
- Drinking water primarily comes from wells, canals, lakes, or rivers.
- Essential services such as education, healthcare, drainage, sanitation, hygiene and transportation are often insufficient or absent.
- Rural regions generally experience minimal air and noise pollution.

Issues with Human Modified Ecosystems

- **Loss of Biodiversity:** Human modification of ecosystems often leads to habitat destruction and fragmentation, resulting in the loss of biodiversity. This can disrupt ecological balance and lead to the decline or extinction of species.
- **Soil Degradation:** Intensive agriculture, urbanization, and other human activities can degrade soil quality through erosion, salinization, compaction and chemical contamination, reducing its fertility and ability to support plant life.
- **Water Pollution:** Human-modified ecosystems often contribute to water pollution through runoff from agricultural fields, industrial activities, and urban areas, carrying pollutants such as pesticides, fertilizers, heavy metals and sewage into water bodies, harming aquatic ecosystems and human health.
- **Climate Change:** Alterations to ecosystems, such as deforestation and urban heat islands, can exacerbate climate change by reducing carbon sequestration, altering local weather patterns, and increasing greenhouse gas emissions.

Steps Taken

- **National Parks and Wildlife Sanctuaries:** India boasts over 100 national parks and 500 wildlife sanctuaries, protecting critical habitats and flagship species like tigers, elephants and rhinos.
- **National River Conservation Directorate (NRCD):** This body works to conserve and rejuvenate India's rivers, tackling pollution and promoting sustainable water management.
- **Soil Health Management Scheme:** This scheme promotes sustainable agricultural practices like compost application and crop residue management, improving soil health and ecosystem services.

Way Forward

- **Sustainable Land Use Planning:** Implementing sustainable land use planning practices that consider ecosystem integrity, biodiversity conservation, and socio-economic needs can help minimize the negative impacts of human activities on ecosystems.
- **Ecosystem Restoration:** Prioritize ecosystem restoration efforts to rehabilitate degraded ecosystems, enhance biodiversity, and improve ecosystem services. This can involve reforestation, wetland restoration and habitat rehabilitation projects.
- **Sustainable Agriculture Practices:** Promote sustainable agriculture practices that prioritize soil health, water conservation and biodiversity conservation, such as organic farming, agro-forestry and integrated pest management.
- **Green Infrastructure Development:** Invest in the development of green infrastructure, such as urban green spaces, green roofs, and permeable pavements, to enhance ecosystem services, mitigate urban heat islands, and improve resilience to climate change.
- **Ecosystem-based Adaptation:** Integrate ecosystem-based approaches into climate change adaptation strategies to enhance resilience and reduce vulnerability to natural disasters, such as restoring coastal mangroves to buffer against storm surges and sea-level rise.

Desertification

Desertification refers to the **degradation of the biological potential** of land, often resulting in desert-like conditions. Human actions, rather than climatic changes or droughts, are the primary drivers of desertification. Desertification is a significant issue in areas adjacent to deserts, spanning regions of Rajasthan, Gujarat, Punjab and Haryana.

Status of Desertification in India

- In 2018-19, desertification affected around 83.69 million hectares of the land.
- This figure surpassed the 81.48 million hectares recorded during 2003-2005 and the 82.64 million hectares during 2011-13.

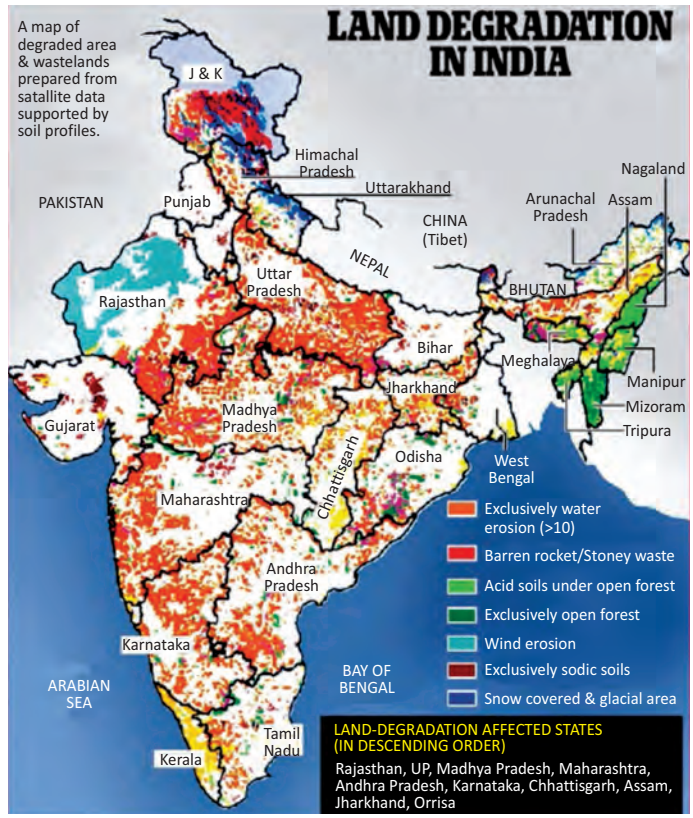


Fig. 2.23: Land Degradation in India

- **State-wise Data:** Rajasthan, Maharashtra, Gujarat, Karnataka, Ladakh, Jharkhand, Odisha, Madhya Pradesh, and Telangana collectively contributed around 23.79% of the area undergoing desertification or land degradation concerning the TGA of the country.

- **Increase in Desertification:** Between 2011-13 and 2018-19, India experienced a rise in desertification levels in 28 out of 31 states and Union territories, as revealed by a detailed analysis of data in the atlas.

Causes of Desertification

- **Population Pressure:** Increasing human population contributes to land degradation.
- **Overgrazing:** Expansion of cattle population leads to overgrazing, damaging vegetation.
- **Agricultural Expansion:** Intensified agriculture accelerates soil erosion and depletion.
- **Development Projects:** Construction activities disrupt natural habitats and soil stability.
- **Deforestation:** Removal of trees reduces soil retention and exacerbates erosion.

Control Measures

- **International Commitment:** India is a signatory to the **United Nations Convention to Combat Desertification** (UNCCD).
- **National Action Programme:** A National Action Programme was formulated in 2001 to combat desertification effectively.
- **Implemented Programmes:** Several major programmes are currently underway to address land degradation and desertification issues:
  - Integrated Watershed Management Programme
  - National Afforestation Programme
  - National Mission for Green India
  - The Mahatma Gandhi National Rural Employment Guarantee Scheme
  - Soil Conservation in the Catchment of River Valley Project and Flood-Prone River Areas

Way Forward

It is imperative to adopt holistic strategies for the conservation and sustainable management of desert ecosystems.

- **Ecosystem Restoration:** Implement initiatives aimed at restoring degraded desert habitats through reforestation, rehabilitation of water sources, and soil conservation measures. This can help to enhance biodiversity, improve soil fertility, and mitigate desertification.
- **Climate Change Adaptation:** Develop and implement adaptive strategies to address the impacts of climate change on desert ecosystems, including changes in precipitation patterns, increased temperatures, and extreme weather events. This may involve the establishment of resilient species, water management techniques, and community-based adaptation measures.
- **Sustainable Land Use Practices:** Promote sustainable land management practices such as rotational grazing, agroforestry, and sustainable agriculture to prevent soil erosion, conserve water resources, and maintain ecosystem integrity.

IGNITE YOUR MIND

From Deforestation to Desertification

Human actions have left an undeniable mark on the Earth's landscapes. Delve into the root causes and far-reaching consequences of deforestation and desertification, two alarming trends that threaten the delicate balance of our planet. Explore potential solutions and chart a course towards a future where both human progress and environmental sustainability can coexist.

CONCLUSION

Terrestrial Ecosystems encompass all land-based life forms, hold paramount importance on Earth. Humanity heavily depends on these ecosystems and their resources. Human activities influence the dynamics of terrestrial ecosystems significantly. Preserving the terrestrial environment is essential for our enduring existence.

Aquatic Ecosystems

3

INTRODUCTION

Aquatic ecosystems, in contrast to land-based terrestrial ecosystems, encompass environments existing in and around water bodies. These diverse ecosystems comprise communities of organisms interdependent on each other and their aquatic surroundings. Aquatic ecosystems play vital roles in nutrient cycling, water purification, climate regulation and in providing habitat for a wide range of species. Their interconnected nature and sensitivity to environmental changes highlight their significance in maintaining ecological balance and supporting life on Earth.

IGNITE YOUR MIND

Beyond the Surface: Diving into the Diverse Realms of Aquatic Ecosystems

Imagine submerging beneath the waves into a world filled with life in various shapes and sizes. What distinct characteristics define different aquatic ecosystems, ranging from freshwater lakes to the expansive ocean? How do they set themselves apart from their terrestrial counterparts?

AQUATIC ECOSYSTEM

Aquatic ecosystems encompass the **plant and animal communities existing within water bodies**, comprising interconnected organisms reliant on each other and their **aquatic surroundings for essential nutrients like nitrogen and phosphorus, as well as for shelter**.

- While ponds, lakes, and rivers are familiar examples, aquatic ecosystems also encompass environments such as floodplains and wetlands, which may experience periodic flooding.
- Surprisingly, apparently hostile aquatic environments can sustain life; for instance, thermal springs host algae and certain insect species despite near-boiling temperatures, tiny worms persist year-round on ice fields, and even heavily polluted waters can harbor large populations of bacteria.

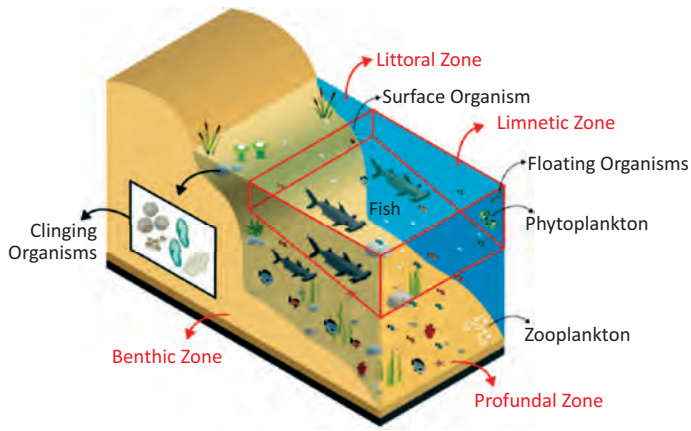


Fig. 3.1: Aquatic Ecosystem

- Notably, even a **minuscule drop of water qualifies as an aquatic ecosystem**, capable of containing or supporting living organisms.

Types of Aquatic Ecosystems

Aquatic environments, characterized by factors like **depth, tidal patterns, temperature, and proximity to landmasses**, are multi-dimensional habitats. They can be categorized into distinct zones. Based on salinity, aquatic ecosystems are classified into the following types:

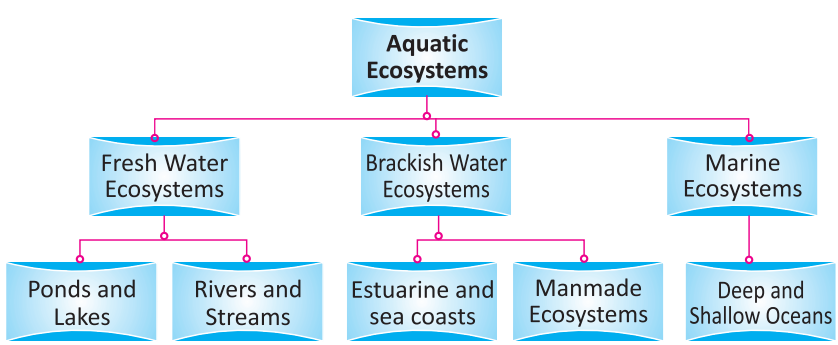


Fig 3.2: Classification of Aquatic Ecosystems

- **Freshwater ecosystems** encompass rivers, lakes and ponds.
- **Brackish Water Ecosystems** include environments such as mangroves and estuaries.
- **Marine ecosystems** comprise oceans, seas, and other saltwater bodies.

FACTORS INFLUENCING AQUATIC HABITAT

Sunlight

- Sunlight diminishes rapidly as it descends through the water column.
- **Depth and Plant Distribution:** The depth to which light penetrates dictates the distribution of plants within a lake.
- **Turbidity:** Suspended particles such as clay, silt and phytoplanktons contribute to water turbidity.
  - **Effect on Light Penetration:** Turbidity restricts the extent of light penetration and consequently limits photosynthetic activity.
- **Zonal Classification:** Aquatic habitats are categorized into **photic and aphotic zones** based on light penetration and plant distribution.

Photic Zone

The photic zone, also known as the **"euphotic" zone**, spans from the surface of the lake to the point where light levels decrease to 1% of those at the surface. The depth of this zone varies based on water transparency.

- **Photosynthetic Activity:** Photosynthesis primarily occurs within the photic zone due to sufficient light availability.
- **Metabolic Processes:** Both photosynthesis and respiration processes take place within the photic zone.

Aphotic Zone

The aphotic zone, also known as the profundal zone, encompasses the lower layers of aquatic ecosystems where light penetration and plant growth are limited. Only respiration activity occurs in this zone.

- **Photosynthetic Activity:** Photosynthetic activities are absent due to lack of sunlight penetration, as photosynthesis relies on light for energy.
- **Metabolic Processes:** These processes occur primarily through chemosynthesis, where organisms utilize chemical energy instead of sunlight to fuel metabolic activities.

Dissolved Oxygen

The average dissolved oxygen content in freshwater is 0.0010 percent by weight (10 parts per million or 10 ppm).

- **Comparison to Air:** This concentration is significantly lower, approximately 150 times, than the oxygen concentration in an equivalent volume of air.
- **Sources of Oxygen:** Oxygen enters the aquatic ecosystem through processes such as the air-water interface and the photosynthetic activities of aquatic plants.
- **Loss of Dissolved Oxygen:** Dissolved oxygen escapes from the water body through processes like the air-water interface and the respiration of organisms such as fish, decomposers, and zooplankton.
- **Effect of Temperature:** The amount of dissolved oxygen retained in water is affected by temperature; oxygen is less soluble in warm water. Additionally, warm water enhances decomposer activity, accelerating oxygen depletion.
  - **Impact on Aquatic Organisms:** When dissolved oxygen levels drop below 3-5 parts per million, many aquatic organisms are at risk of dying due to oxygen deprivation.

Winterkill

This phenomenon, where fish perish due to oxygen depletion in shallow, ice-covered water bodies, is termed winterkill.

- **Effects of Ice Layer:** The formation of an ice layer atop a water body can obstruct light penetration, halting photosynthesis while respiration persists.
- **Depletion of Oxygen:** In shallow water bodies, oxygen depletion occurs, leading to the death of fish and other aquatic organisms.

Temperature Effects

- **Narrow Tolerance Limits:** Aquatic organisms have narrow temperature tolerance limits due to the relatively stable nature of water temperatures.
- **Vulnerability to Temperature Changes:** Even minor fluctuations in water temperature pose significant threats to the survival of aquatic organisms, surpassing the impact of temperature changes experienced by terrestrial organisms.

Transparency

- Aquatic productivity is influenced by transparency, which acts as a constraint.
- Transparency affects the penetration of light in water bodies.
- Turbidity caused by suspended particles like clay, silt, phytoplankton, and others reduces light penetration and consequently hinders photosynthetic activity.

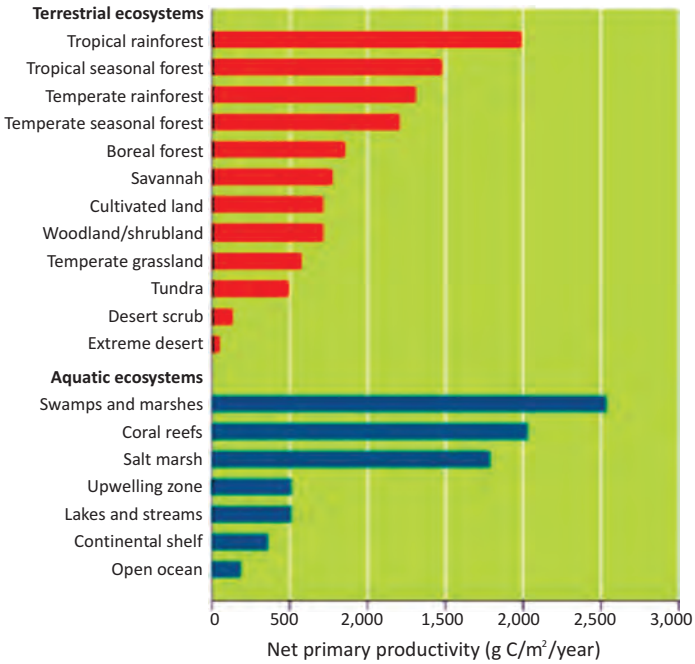


Fig 3.3: Net Primary Productivities of Various Ecosystems

In conclusion, the diverse array of aquatic habitats worldwide harbors remarkable creatures. Despite their vastness and enigmatic nature, aquatic ecosystems remain largely unexplored, with scientists estimating only about 10% of resident organisms documented.

FRESHWATER ECOSYSTEMS

Freshwater ecosystems constitute a distinct category within the broader realm of aquatic ecosystems found on Earth. They consist of water bodies located on land, characterized by a continuous cycle of water and possess low salt content, typically **below 5 parts per thousand (ppt)**. Examples of freshwater ecosystems include lakes, ponds, rivers, streams, springs, bogs and wetlands.

Types of Freshwater Ecosystems

Lentic Ecosystem

A lentic ecosystem, also known as a lacustrine ecosystem, encompasses all environments characterized by static or still water.

- **Biodiversity:** Various organisms such as algae, crabs, shrimp, and amphibians like frogs and salamanders inhabit these environments.
- **Alternative Name:** Lentic ecosystems are also referred to as still water ecosystems.
- **Diverse Range:** Lentic systems vary greatly in size, ranging from small, transient rainwater puddles only a few inches deep to vast bodies of water like Lake Baikal, which boasts a maximum depth of 1,642 metres.
- **Examples:** Lakes and ponds represent typical examples of lentic ecosystems.

Lotic Ecosystem

Lotic ecosystems primarily encompass swiftly flowing water bodies characterized by unidirectional movement, such as rivers and streams.

Fig 3.4: Lotic and Lentic Ecosystems

- **Biodiversity:** These environments support a wide variety of organisms, including beetles, mayflies, stoneflies, and diverse fish species like trout, eel, and minnow.
- **Alternative Name:** Lotic ecosystems are also known as riverine ecosystems.
- **Characteristics:** Essential features of lotic ecosystems include the presence of air gases, turbidity, longitudinal temperature gradients, and dissolved materials throughout the water body from its source to its mouth.
- **Zones:** Lotic ecosystems typically consist of two main zones: rapids and pools.

Freshwater Ecosystem Characteristics

- **Extensive Coverage:** Cover less than 1% of Earth's surface but hold only 0.8% of its water.
- **Seasonal Temperatures:** During summer, temperatures typically range between 65 to 75 degrees Fahrenheit, while in winter, they range from 35 to 45 degrees Fahrenheit within freshwater biomes.
- **Dominant Flora:** Grasses and sedges, with occasional trees. Examples: Mangroves, Spike Rush, Water Lily, Cattail, Cyanobacteria.
- **Diverse Fauna:** The freshwater biome supports a diverse array of species, including over 1,200 amphibian species, 700 fish species, and a variety of invertebrates.
- **Benefit of Salt-Free Water:** Animals and plants thrive in freshwater due to its absence of harsh salt, unlike other environments.
- **Vital Role:** Freshwater biomes are crucial for Earth's ecology, supporting unique climates and a rich tapestry of life.

Significance

- Freshwater ecosystems, encompassing lakes, rivers, ponds, streams, wetlands, and bogs, may constitute a mere 1% of Earth's surface, but their significance is monumental.
- **Biodiversity hotspots:** They harbor more than 10% of the world's known species, despite covering only 1% of the planet's surface. Over 41% of all fish species call freshwater home, alongside 1/3 of amphibians and 1/3 of all mammal species depending on freshwater for some part of their lifecycle.
- **Drinking water source:** Over 3 billion people rely on freshwater ecosystems for their drinking water needs.

- **Sustainable livelihoods:** Freshwater ecosystems support 1 in 10 jobs globally, with fisheries, aquaculture, tourism, recreation, and transportation generating trillions of dollars annually.
- **Food security:** Inland fisheries provide 20% of animal protein for over 3.1 billion people globally.

Threats

- **Alarming Population Decline:** The **Living Planet Index** by the **World Wide Fund for Nature** reveals an 83% decrease in freshwater vertebrate populations since 1970.
- **Broad Threats to Biodiversity:** Five major threats endanger freshwater biodiversity; overexploitation, water pollution, flow alteration, habitat destruction or degradation, and invasion by non-native species.
- **Contributing Factors to Extinction:** Recent extinction patterns in freshwater ecosystems are influenced by sedimentation, stream fragmentation, chemical and biological contaminants, dam constructions, and the introduction of invasive species.
- **Chemical Pressures on Ecosystem Health:** Acidification, eutrophication, as well as pollution from copper and pesticides, are common chemical stressors impacting the health of freshwater ecosystems.

NITI Aayog reports that a significant portion of India's population experiences severe to extreme water scarcity.

- Despite comprising 16% of the global population, India holds just **4% of the world's freshwater reservoirs**.
- **By 2060, North India**, the most densely populated region, is predicted to confront severe and irreversible freshwater scarcity due to diminishing resources exacerbated by climate change.

Initiative Taken for Freshwater Conservation

- **National Water Policy, 2012:** This policy aims to achieve sustainable water management through various measures, including rainwater harvesting, water conservation and pollution control.
- **Pradhan Mantri Krishi Sinchayee Yojana:** This scheme aims to improve water use efficiency in agriculture through micro-irrigation systems and other measures.
- **Jal Shakti Abhiyan- Catch the Rain Campaign:** This campaign aims to create awareness about rainwater harvesting and to promote its adoption across the country.
- **Atal Bhujal Yojana:** This scheme aims to improve groundwater management through various measures, including rainwater harvesting, artificial recharge, and watershed development.

IGNITE YOUR MIND

A Delicate Balance: Understanding Threats to Aquatic Ecosystems

While nature thrives in its pristine state, human activities have significantly impacted aquatic ecosystems. How do human-made structures like dams and reservoirs alter these ecosystems, and what are the potential consequences?

Way Forward

- **Sustainable Groundwater Management:** Implementation of effective strategies is essential, including rural-urban collaborative initiatives for replenishing groundwater through artificial recharge and household-level rainwater harvesting.
- **Water Conservation Zone:** Shifting attention towards improved water governance is imperative, along with enhancing data accuracy regarding the condition of water bodies at regional, state, and national scales.
- **Leveraging Modern Water Management Techniques:** Integration of Information Technology with water-related databases is crucial for efficient management. Key techniques such as Electrodialysis Reversal (EDR), Desalinization, Nanofiltration, as well as Solar and UV Filtration are frequently utilized to achieve clean and potable water.

Lake

Ramsar Convention on Wetlands defines a lake as "a body of water that is wholly or partly surrounded by land, and which contains permanent or temporary water." It is described as **a body of water of varying size, contained within a basin and bordered by land, lakes can have connecting rivers and outlets.** Positioned on land rather than within the ocean, lakes typically surpass ponds in size.

They contain standing water rather than flowing water. Broadly, they can be **classified in the following manner.**

Classification of Lakes

- **Temporary Lakes:** Temporary lakes form after heavy rainfall, filling small depressions in undulating terrain. Evaporation exceeds precipitation in these lakes. **Example:** In India, temporary lakes can appear in the **Thar Desert** after monsoon rains.
- **Permanent Lakes:** Permanent lakes maintain water levels consistently, with precipitation exceeding evaporation. These lakes are typically deep and hold more water than could be evaporated. **Example:** Wular lake in Jammu & Kashmir and Chilika Lake in Odisha.
- **Freshwater Lakes:** The majority of lakes worldwide are freshwater lakes, fed by rivers and with out-flowing streams. **Example:** Dal Lake in Jammu & Kashmir and Nainital Lake in Uttarakhand.

- **Saline Lakes:** Saline lakes, also known as salt lakes can form in areas without natural outlets or where water evaporates rapidly, resulting in high salt content. Intense evaporation leads to a negative freshwater balance, causing increased salinity. **Examples** include the Great Salt Lake, the Aral Sea, and the Sambhar Salt Lake in Rajasthan.
- **Natural Lakes:** They are typically located in mountainous regions and rift zones, resulting from various processes such as A) Shifting of mountain ranges caused by tectonic activity. B) Landslides or global seepage events. C) The formation of lagoons through the accumulation of spits and bars. **Example:** Vembanad Lake(Kerala), manmade lake by Koyna Dam Pangong Lake(Ladakh), etc.
- **Artificial Lakes:** They are built or created by humans, primarily for industrial or agricultural use. Additionally, they serve purposes such as irrigation, hydroelectric power generation, and domestic water supply. **Example:** Dhebar Lake(Rajasthan), Gobind Sagar (Himachal Pradesh), Kodaikanal (Tamil Nadu), Ana Sagar Lake(Rajasthan), etc.

Classification Based on Nutrient Content

Feature	Oligotrophic Lake	Mesotrophic Lake	Eutrophic Lake
Nutrient levels	Low	Moderate	High
Water clarity	High	Moderate	Low
Productivity	Low	Moderate	High
Plant life	Sparse	Moderate	Abundant algae and aquatic plants
Fish species	Cold-water fish (trout, salmon)	Mixed fish populations (trout, bass, panfish)	Rough fish (carp, catfish)
Examples	Lake Tahoe (USA), Crater Lake (USA)	Lake Michigan (USA), Lake Geneva (Switzerland)	Lake Erie (USA), Laguna de Bay (Philippines)

Lake Cleaning Methods

- **Mechanical Removal:**
  - **Boats and Barges:** Equipped with skimmers, nets and conveyors for debris collection.
  - **Dredging:** Extracts pollutants and nutrients from bottom sediments.
- **Biological Control:**
  - **Biomanipulation:** Introduces predatory fish to regulate algae and invasive plants.
  - **Phytoremediation:** Uses aquatic plants to absorb excess nutrients.
- **Chemical Treatment:**
  - **Herbicides:** Targeted application to control specific plant species.
  - **Algae Control Agents:** Manages algae blooms with ecological considerations.
  - **Alum Treatment:** Reduces nutrient levels and clarifies the lake by adding aluminum sulfate.
- **Natural Methods:**
  - **Buffer Strips:** Vegetation around the lake filters runoff and prevents pollution.
  - **Constructed Wetlands:** Man-made ecosystems filter water before entering the lake.
  - **Floating Wetlands:** Artificial islands with floating vegetation absorb nutrients.
- **Innovative Technologies:**
  - **Autonomous Robots:** Navigate to collect debris and invasive plants.
  - **Ultraviolet Light:** Purifies water by eliminating harmful bacteria and algae.
  - **Aeration:** Adds oxygen to the water using mechanical aerators or diffusers.
  - **Ozone Treatment:** Introduces ozone to oxidize and eliminate contaminants.
- **Other Strategies:**
  - **Biological Augmentation:** Introduces beneficial micro-organisms to enhance natural processes.
  - **Stormwater Management:** Controls and treats stormwater runoff before it enters the lake.

Major Indian Lakes and Relevant Facts

Lake	State	Characteristics
Vembanad Lake	Kerala	This lake, Kerala's largest and the **longest in the country,** is nourished by the Meenachil, Achankovil, Pampa, and Manimala rivers.
Chilika Lake	Odisha	Chilika Lake is a **brackish water lake** and a shallow lagoon with estuarine character. It's home to some rare and threatened species, including the green sea turtle, Irrawaddy dolphin, dugong, blackbuck, and fishing cat. **India's first Ramsar Convention wetland** of international significance in 1981.
Pulicat Lake	Andhra Pradesh & Tamil Nadu	Pulicat Lake is the second largest brackish water lagoon in India after Chilika Lake.

Loktak Lake	Manipur	The largest freshwater **lake in North-East India, KeibulLamjao,** is the sole floating national park globally and serves as the last refuge for the critically endangered Sangai or Manipur brow-antlered deer.
Nagarjuna Sagar Lake	Telangana and Andhra Pradesh	Nagarjuna Sagar, a **man-made freshwater lake** and water reservoir, is created by the Nagarjuna Sagar Dam, constructed in 1967.
Sambhar Lake	Rajasthan	India's **largest inland salt lake**, which represents the Aravalli Range depression, was utilized by the **Mughal empire for its salt resources**, later divided between the princely states of Jaipur and Jodhpur.
Wular Lake	Jammu and Kashmir	This lake, **formed due to tectonic activity,** is **Asia's second largest freshwater lake** and India's largest freshwater lake, nourished by the Jhelum River and the Madhumati stream.
Dal Lake	Jammu and Kashmir	It is referred to as the **"Jewel in the Crown of Kashmir"** or "Srinagar's Jewel" due to its significance in tourism and recreation in the region.
Renuka Lake	Himachal Pradesh	Renuka Lake is a wetland that is home to at least 443 species of fauna. It is also home to many big fish and has been **designated as a Ramsar site since 2005**

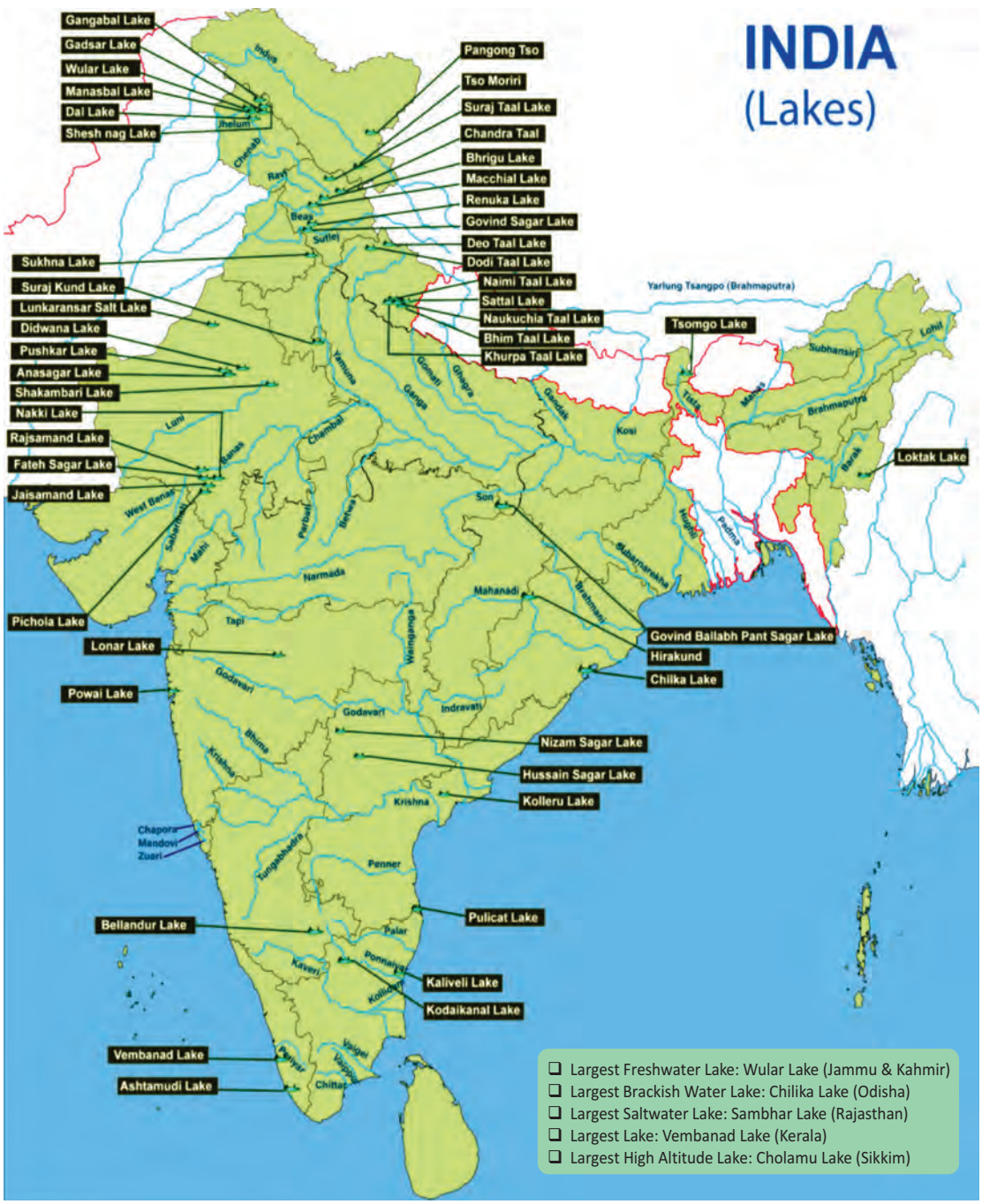


Fig. 3.5: Important Lakes of India

Ameenpur Lake (First Biodiversity Heritage Site)

- Ameenpur, situated in the **Sangareddy district of Telangana, India**, and located on the periphery of Hyderabad, is a small lake **celebrated for its substantial population of migratory birds.**
- Ameenpur Lake, a **man-made water body**, has a historical origin dating back over 300 years, attributed to the efforts of Abdul Qadir Amin Khan of Patancheru, during the reign of Ibrahim Qutb Shah (reign 1550-1580 AD).
- Recognizing its ecological significance, the Ministry of Environment conferred upon Ameenpur the **status of a Biodiversity Heritage Site in November 2016**, in accordance with the Biological Diversity Act of 2002. This distinction marks Ameenpur as the inaugural water body in India to receive such recognition and notably, the premier biodiversity site endorsed within an urban setting.
- Ameenpur Lake hosts a diverse ecosystem, with the **number of species recorded at 186** during the latest survey conducted in 2016, representing an increase from the previous count of 171 species in 2015.

Significance of Lakes

- **Water Cycle Contribution:** Acting as natural reservoirs, lakes collect precipitation and runoff from their watersheds, which includes all streams and rivers flowing into them. This process is fundamental to the water cycle, that aids in water filtration and storage.
- **Agricultural Support:** Farmers rely on lake water for irrigating crops, making lakes critical to agriculture. The availability of freshwater helps in sustaining crop production.
- **Climate Moderation:** Large lakes influence local climates through the "lake effect", where winds across lakes moderate temperatures on adjacent lands. This effect is due to water's slower response to temperature changes compared to land, helping to stabilize local climates.
- **Extended Growing Seasons:** In autumn, lakes can warm the air, delaying frost and extending the growing season for agriculture. Conversely, in spring, cool lake breezes can protect crops from frost onset is in autumn overheating, beneficial for young plants.
- **Water Supply and Drought Mitigation:** Many communities depend on lakes for their freshwater supply. Artificial lakes, created by dams, are particularly valuable for storing drought-resistant water supplies and generating hydroelectric power.
- **Habitat and Community:** For some people, lakes are more than just resources; they are home. Communities built around lakes depend on them for their lifestyle, culture and economy.

Challenges

- **Nutrient loading:** Agricultural runoff, sewage discharge and industrial waste introduce excessive nutrients, that lead to harmful algal blooms that deplete oxygen and harm aquatic life.
- **Microplastics:** Tiny plastic fragments contaminate the water, harming fish, birds and other animals who ingest them.
- **Shoreline development:** Encroaches on natural habitat, impacting fish spawning grounds and bird nesting sites.
- **Rising temperatures:** High temperatures can lead to thermal stratification, reducing oxygen levels in deeper water and harming cold-water fish.

Initiatives Taken

- **National Water Policy, 2012:** This policy emphasizes the importance of conserving water bodies, including lakes, through measures like rainwater harvesting and pollution control.
- **Jal Shakti Abhiyan:** This mission, launched in 2019, focuses on water conservation and includes efforts to rejuvenate lakes through community participation and desilting initiatives.
- **Atal Bhujal Yojana:** This scheme targets groundwater management but also promotes rainwater harvesting and watershed development, indirectly benefiting lakes by replenishing their sources.
- **National Plan for Conservation of Aquatic Eco-systems (NPCA):** This initiative is a **conservation program targeting wetlands and lakes**, formulated by amalgamating the National Lake Conservation Plan and the National Wetlands Conservation Programme. Operating as a centrally-sponsored scheme, it is currently administered by the Ministry of Environment, Forest and Climate Change (MoEFCC).

National Plan for Conservation of Aquatic Ecosystems (NPCA)

Objective:

- Conserve and restore lakes in India, focusing on **restoring ecological balance**, **improving water quality**, and **enhancing biodiversity**.

Implementation:

- Currently being implemented by the MoEFCC, and was formulated by merging the National Lake Conservation Plan and the National Wetlands Conservation Programme.

Components of NPCA:

- **Survey and Assessment:** Continues to assess lakes' ecological health, but with a stronger focus on **climate change impacts** and **ecosystem services valuation**.
- **Detailed Project Reports (DPRs):** Updated to include **climate-resilient solutions**, **nature-based solutions**, and **wastewater treatment infrastructure**.

- **Implementation of Conservation Measures:** Expands to include **buffer zone restoration, sustainable fishing practices, and invasive species control**.
- **Capacity Building and Awareness:** Increased focus on **community-based participation**, **knowledge sharing**, and **public education campaigns**.
- **Monitoring and Evaluation:** Regular monitoring with updated metrics to assess progress towards **ecological restoration, water quality improvement, and biodiversity enhancement**.

Funding:

- **Central Government:** Provides financial assistance based on project prioritization and **performance-based funding mechanisms**.
- **Exploration of innovative financing options:** Public-private partnerships, Corporate Social Responsibility initiatives, and green bonds.

Significance:

- **Enhanced focus on:** Ecosystem services like **flood control, carbon sequestration, and recreation**.
- **Contribution to Sustainable Development Goals (SDGs):** SDG 6 (Clean Water and Sanitation), SDG 14 (Life Below Water), and SDG 15 (Life on Land).

Critical Analysis

- **Lack of Comprehensive Planning:** Sometimes, government initiatives lack comprehensive planning, including inadequate assessment of the ecological, social, and economic aspects of lake management. Without a holistic understanding of the lake ecosystem and its surrounding areas, initiatives may not address underlying issues effectively.
- **Insufficient Funding and Resources:** Limited financial resources and inadequate allocation of funds can hinder the implementation of lake management initiatives. Insufficient funding may lead to delays in infrastructure development, monitoring programs, and restoration activities, impacting the overall effectiveness of the initiatives.
- **Poor Governance and Coordination:** Inefficient governance structures, overlapping jurisdictions, and poor coordination among different government agencies responsible for lake management can result in fragmented approaches and conflicting priorities. Lack of coordination often leads to duplication of efforts, inefficiencies, and gaps in implementation.

Way Forward

- As a lake mirrors its surrounding catchment area, it is crucial to initially assess any significant changes or patterns in the primary land uses within the catchment area or watershed that feeds into the lake.
- There isn't a standardized method that outlines the planning process for developing short, medium, and long-term action plans for the revitalization of lakes, taking into account their watershed areas.
- It is imperative to establish a comprehensive document delineating the watershed area of the lake, along with clear objectives and goals, and develop time-bound action plans accordingly.
- The conservation of lakes and wetlands necessitates an integrated and multidisciplinary approach, supported by a unified regulatory framework.

Conclusion

Lake ecosystems are vital for biodiversity, resources and human well-being. Despite facing threats like pollution and climate change, conservation efforts and community engagement are crucial for their preservation. By prioritizing sustainable management, we can safeguard these ecosystems and their benefits for future generations.

In the context of pollution in lake ecosystems, **eutrophication** serves as a precursor to **harmful algal blooms,** significantly impacting aquatic life. The excessive influx of nutrients into lakes fuels algal growth, leading to blooms that deplete oxygen levels, suffocate fish, and produce toxins harmful to both aquatic organisms and humans. Managing eutrophication is critical for preventing these blooms and maintaining the health of lake ecosystems. **In the following discussion, we will provide a comprehensive explanation of both eutrophication and harmful algal blooms in aquatic ecosystems.**

Eutrophication

Eutrophication refers to the phenomenon where an excess of nutrients accumulates in a body of water, leading to the proliferation of basic plant organisms. This is characterized by the **rapid growth, or bloom, of algae and plankton.**

- Eutrophication, also known as **hypertrophication**, occurs when a body of water experiences excessive growth of plants and algae due to high levels of minerals and nutrients. While some lakes naturally undergo eutrophication as they age, human activities, such as the use of fertilizers, have accelerated this process in many freshwater systems.
- This phenomenon is now recognized as a **significant environmental concern**, alongside issues like deforestation, global warming and ozone layer depletion, due to its detrimental impact on natural ecosystems, worsened by increasing human populations and expanding agricultural development.
- **Example:** Eutrophication of the Vaigai river in Madurai.

Process of Eutrophication

- **Eutrophication, an ecosystem syndrome,** occurs due to the influx of natural or artificial nutrients like nitrates and phosphates into aquatic environments through sources like fertilizers and sewage.

- **The primary cause** is the leaching of phosphates and nitrates from agricultural lands into lakes or rivers.

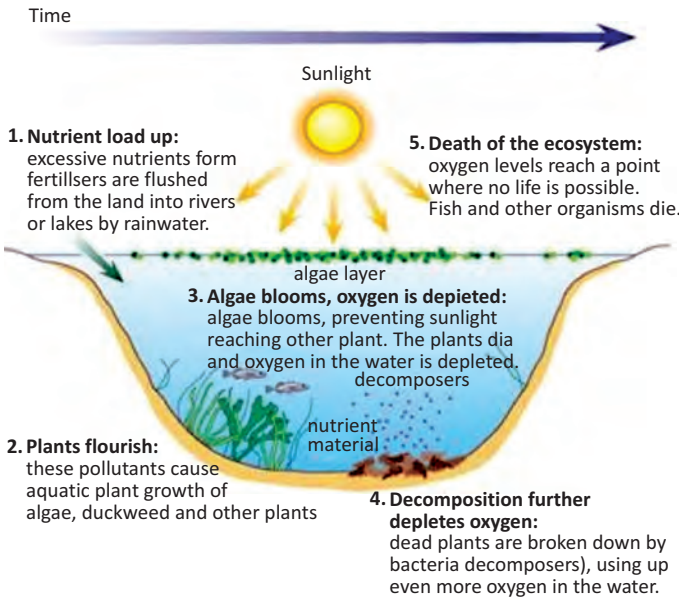

Time
Sunlight
1. Nutrient load up:
excessive nutrients form fertillsers are flushed from the land into rivers or lakes by rainwater.
5. Death of the ecosystem:
oxygen levels reach a point where no life is possible. Fish and other organisms die.
algae layer
3. Algae blooms, oxygen is depieted:
algae blooms, preventing sunlight reaching other plant. The plants dia and oxygen in the water is depleted.
decomposers
nutrient material
2. Plants flourish:
these pollutants cause aquatic plant growth of algae, duckweed and other plants
4. Decomposition further depletes oxygen:
dead plants are broken down by bacteria decomposers), using up even more oxygen in the water.

Fig. 3.6: Process of Eutrophication

- **The visible consequence** of eutrophication is the proliferation of green algae on the surface layer of lakes. Algae and blue-green bacteria thrive on the excess nutrients, leading to an **algal bloom** where the surface layer becomes densely covered. However, this rapid growth is unsustainable.
- **The algal bloom blocks sunlight penetration,** affecting the photosynthesis process crucial for oxygen production by green plants.
- The explosion in population **reduces oxygen levels,** exacerbated by microorganisms consuming oxygen during algae decomposition.
- Low oxygen levels lead to **suffocation and death of fish and other aquatic organisms.**
- Anaerobic conditions **favor the growth of toxin-producing bacteria** harmful to aquatic life, birds and mammals.
- Ultimately, eutrophication results in the **deterioration of aquatic ecosystems** and the demise of its inhabitants.
- **This process often induces shifts in animal and plant populations** and contributes to the decline in water and habitat quality.

Types of Eutrophication

- **Natural Eutrophication:** Natural eutrophication stems from an excess of nutrients in water bodies due to natural processes like floods.
  - During flooding, nutrients from the land are carried and deposited into lakes or rivers, fostering the growth of algae and basic plant life.
  - This process occurs gradually over time and is influenced by environmental factors such as temperature, with potential amplification due to global warming.
- **Man-made Eutrophication:** Anthropogenic eutrophication is driven by human activities, particularly the use of fertilizers on agricultural crops, lawns, and golf courses.
  - Rainfall washes these fertilizers into water bodies, providing abundant nutrients to algae and plankton, thus accelerating eutrophication.
  - Overpopulation exacerbates this process through industrial expansion and deforestation, leading to increased soil erosion and the deposition of phosphorus-rich soil into water bodies.
  - Additionally, the discharge of sewage and industrial wastes introduces further nutrients and pollutants into aquatic ecosystems, further accelerating eutrophication.

Major Causes of Eutrophication

- **Fertilizers:** Agricultural fertilizers, rich in **phosphates and nitrates, are extensively** used to boost crop yields. Runoff from fertilized fields carries these nutrients into water bodies, fueling algal growth. Increased nutrient availability promotes algal blooms, leading to eutrophication.
- **Concentrated Animal Feeding Operations (CAFOs):** Large-scale animal farming generates significant amounts of nitrogen and phosphorus-rich manure. Discharge of manure into water systems elevates nutrient levels, stimulating algal proliferation. Excess nutrients overcome natural limitations on algal biomass, exacerbating eutrophication.
- **Sewage and Industrial Waste Discharge:** Untreated household sewage and industrial effluents contain high concentrations of nutrients. Release of such wastewater into water bodies enhances nutrient availability, fostering algal bloom formation.
- **Environmental Factors:** Temperature, salinity, and atmospheric conditions influence eutrophication dynamics. Algal blooms thrive within specific temperature and salinity ranges.

Effects of Eutrophication

- **Change in Ecosystem**: Eutrophication leads to the formation of a detritus layer in ponds and lakes, accompanied by a decrease in surface water depth. Over time, affected bodies of water transition into marshes, shifting from aquatic to terrestrial ecosystems.
- **Decreased Biodiversity:** Algal blooms impede sunlight penetration, impacting photosynthetic plants and causing their death.
  - Decomposition of dead plants consumes oxygen, creating an oxygen-depleted environment.
  - Ultimately, this oxygen depletion leads to the demise of all organisms within the aquatic ecosystem.

- **New Species Invasion: Eutrophication can increase ecosystem competitiveness** by transforming previously limited nutrients into abundant ones, altering species composition.
- **Toxicity:** Certain algae species release **neurotoxins** and **hepatotoxins** during blooms in eutrophic waters. These toxins can bioaccumulate in shellfish and other marine species, posing risks to various animals, including humans who consume contaminated seafood.
- **Increase in Biological Oxygen Demand (BOD): Algal blooms,** a consequence of eutrophication, contribute to increased organic matter in water bodies. Decomposition of this organic matter by bacteria consumes significant oxygen, elevating the Biological Oxygen Demand (BOD) and leading to **hypoxia**, detrimental to aquatic life.
  - **Biological Oxygen Demand (BOD)** is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a given water sample at a certain temperature over a specific time period. BOD is often used in wastewater-treatment plants and is used as an index of the degree of organic pollution in water.

Riparian Buffers for Mitigation of Eutrophication

- **Riparian buffers are vegetative zones** established along water bodies, farms, roads, and other areas to mitigate pollution.
- **They act as interfaces** between land and water, trapping sediments and nutrients to prevent direct deposition into water bodies.
- **Both natural (such as wetlands and estuaries) and artificial** riparian buffers serve to reduce pollution influx into aquatic ecosystems.
- **Phytoremediation**, the use of plants to remove contaminants, is a crucial mechanism within riparian buffers for filtering pollutants.

Mitigation of Eutrophication

- **Wastewater Treatment:** Prior to discharge into water bodies, wastewater undergoes treatment to reduce nutrient levels.
- **Harvesting:** Monitoring and managing nutrient recycling through harvesting practices.
- **Source Control:** Reduction of nitrogen and phosphorus at their sources and implementing measures to separate nutrient-rich streams from receiving bodies.
- **Algal Debris Management:** Removal of dead algae to prevent further nutrient release during decomposition.
- **Chemical Precipitation:** Utilization of chemical precipitation methods, such as alum, lime, iron, and sodium aluminate, to remove excess phosphorus effectively.
- **Physicochemical Approaches:** Employing methods like electrodialysis, reverse osmosis, and ion exchange to eliminate nutrients.
- **Biological Control:** Use of Copper Sulphate and Sodium Arsenite to control algae and rooted plant populations, respectively, aiding in eutrophication mitigation efforts.

Conclusion

Globally, rivers today discharge twice the amount of organic matter into oceans compared to prehuman eras, with nitrogen and phosphorus fluxes more than doubling. This significant increase in carbon, nitrogen, and phosphorus loading has led to cultural eutrophication in numerous marine systems. Enhanced pollution management and adoption of improved municipal, industrial, and agricultural practices hold promise for substantially mitigating both inland and coastal eutrophication.

Harmful Algal Blooms (HABs)

Harmful Algal Blooms (HABs) are instances where algae colonies experience rapid, uncontrolled growth, leading to adverse effects on various organisms including humans, fish, shellfish, marine mammals, and birds. While commonly known as **"red tides"** by the public, experts prefer the term "harmful algal blooms" to accurately capture the potential risks associated with these occurrences.

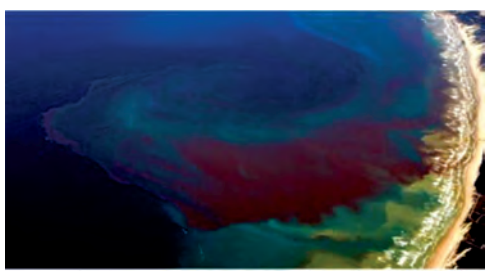


Fig. 3.7: Harmful Algal Bloom

- **Harmful algal blooms can manifest in marine as well as freshwater settings**, evident through the discoloration of the water's surface. These blooms typically arise following the introduction of nutrients like nitrogen or phosphorus into aquatic habitats.
- **Algae, encompassing both unicellular and multicellular** photosynthetic organisms, contribute to these occurrences. Unicellular algal blooms are distinguished by water discoloration, while multicellular blooms may manifest in the form of expansive kelp forests.
- **Example:** Florida's Red Tide.

Causes of Harmful Algal Blooms

- **Eutrophication:** Algae and cyanobacteria thrive on nutrients, particularly in eutrophic (nutrient-enriched) waterways.
  - Eutrophication leads to an excess of nutrients in water bodies, promoting the overgrowth of simple plant life, including harmful algae.
- **Temperature:** Ambient temperature plays a crucial role in the proliferation of harmful algal blooms. These blooms are more prevalent in warmer seasons, such as summer and fall, although they can occur throughout the year.

- **Turbidity:** Turbidity, caused by suspended particles and organic matter, influences light penetration into the water column.
  - Reduced turbidity allows more light to reach the water, creating favorable conditions for algal growth and bloom formation.

Implications of Harmful Algal Blooms

- **Impact on Marine Life:** Harmful Algal Blooms (HABs) consist of toxin-producing species that damage marine organisms either by producing biological toxins or interfering with their mechanical functions.
- **Human Health Risks: Pollutants from HABs** can accumulate in seafood, posing risks to humans when consumed.
  - **Example:** Consumption of contaminated shellfish can result in neurotoxic shellfish poisoning, paralytic shellfish poisoning, diarrheal shellfish poisoning, and amnesic shellfish poisoning.
- **Restriction of Sunlight and Oxygen Depletion:** Algal blooms limit sunlight penetration, leading to the death of aquatic plants and reduced oxygen replenishment. Oxygen deprivation caused by algal blooms can result in the death of primary consumers like small fish, disrupting the food chain and affecting higher life forms.
- **Loss of Coral Reefs:** Decreased water transparency due to increased turbidity from algal blooms can lead to loss of coral reefs.

Mitigation of Harmful Algal Blooms (HABs)

- **Effluent Treatment:** Utilize multiple treatment processes to effectively remove algal toxins from effluent. Employ tertiary sewage treatment procedures before discharging sewage into rivers and lakes to remove phosphate and nitrate.
- **Nitrogen Testing and Modeling:** Implement N-Testing to accurately determine the required quantity of fertilizer for crop plants, thus reducing nitrogen release into the environment.
- **Reduction of Vehicle and Power Plant Emissions:** Implement measures to reduce nitrogen emissions from vehicles and power plants, which contribute to nutrient loading in water bodies.
- **Phosphate Reduction in Detergents:** Reduce the usage of phosphates as detergent builders to limit nutrient input into aquatic ecosystems and mitigate algal blooms.

Harmful algal blooms cause economic losses, including increased drinking-water treatment expenses and reduced revenue from recreation, aquaculture, and fisheries. India's Algal Bloom Information Service (ABIS) offers timely updates on toxic blooms, aiding coastal fisheries and residents' health. The Oceansat-2 satellite, launched in 2009, enhances monitoring capabilities with global ocean colour observation.

BRACKISH WATER ECOSYSTEM

Brackish water ecosystems occur where freshwater mixes with seawater, resulting in a unique salinity level ranging from 0.5 to 30 parts per thousand. These ecosystems encompass various habitats, including **estuaries, salt marshes, and mangrove swamps and forests.** An exemplary instance is the River Thames, flowing through London, which represents a typical river estuary.

Types of Brackish Water Ecosystems

Brackish water ecosystems, where freshwater meets saltwater, are incredibly diverse and vital environments harboring unique flora and fauna. Here are some of the most common types:

- Estuaries
- Lagoons
- Salt Marshes

Significance of Brackish Water Ecosystems

- **Biodiversity Hotspots:** Brackish water ecosystems support a remarkable variety of plant and animal life, including many species found nowhere else. They serve as vital nursery grounds for numerous fish, crustaceans, and birds, contributing significantly to overall marine biodiversity.
- **Habitat Provision:** These ecosystems provide diverse habitats for diverse organisms, including mangroves, salt marshes, and seagrass meadows, each crucial for specific species. These habitats offer shelter, feeding grounds, and breeding grounds for various life stages.
- **Water Filtration:** Brackish wetlands act as natural filters, trapping sediments and pollutants from land runoff before they reach open ocean environments. This helps maintain water quality and protects sensitive marine ecosystems.
- **Coastal Protection:** Mangroves and salt marshes act as natural buffers against storms and rising sea levels, protecting coastal communities and infrastructure from wave damage and erosion. They also help stabilize shorelines and prevent soil loss.
- **Fisheries:** Brackish water ecosystems support lucrative fisheries due to their high productivity and abundance of commercially valuable species like shrimp, oysters and crabs. They contribute significantly to local economies and livelihoods.
- **Tourism:** These ecosystems offer unique recreational opportunities like boating, fishing, bird-watching and wildlife viewing, attracting tourists and generating revenue for local communities.

Challenges

- **Fluctuating salinity:** Salinity levels in brackish water environments can vary significantly due to tides, freshwater inflows, and evaporation. This can be stressful for organisms adapted to a specific salinity range.

- **Extreme weather events:** Storms, floods, and droughts can drastically alter salinity levels and disrupt the delicate balance of these ecosystems.
- **Pollution:** Runoff from agricultural lands, industrial waste, and sewage can contaminate these ecosystems, harming aquatic life and disrupting food webs.
- **Habitat destruction:** Coastal development, dredging, and unsustainable fishing practices can destroy critical habitats for species that rely on brackish water environments.
- **Overexploitation:** Overfishing and excessive resource extraction can put undue pressure on populations of fish, shellfish, and other organisms.

Initiative Taken for Conservation

- **UNDP-GEF Small Grants Programme (SGP):** This program supports community-based conservation projects in developing countries, including India. Several SGP projects have focused on restoring and managing brackish water ecosystems, promoting sustainable fishing practices, and raising awareness about their importance.
- **World Wildlife Fund (WWF):** WWF works in India on various conservation initiatives, including those focused on mangroves and coastal ecosystems. They support mangrove restoration projects, promote sustainable resource management, and advocate for policies that protect brackish water ecosystems.
- **National Biodiversity Action Plan (NBAP):** This plan recognizes the importance of brackish water ecosystems and outlines strategies for their conservation, including research, awareness campaigns, and management plans.
- **Integrated Coastal Zone Management (ICZM) Programme:** This program focuses on managing coastal areas sustainably, including protecting brackish water ecosystems. It encourages stakeholders participation, promotes conservation measures, and implements regulations for pollution control and habitat protection.

Critical Analysis

Effective policies for brackish water ecosystems must address vulnerabilities to climate change and environmental pressures. However, critical analysis reveals gaps in adaptive management, research, socio-economic consideration, and public awareness, which can undermine policy success. Addressing these shortcomings is crucial for ensuring the effectiveness of ecosystem protection measures.

Way Forward

- **Protected Areas:** Designating and effectively managing protected areas for vulnerable habitats like mangroves and salt marshes.
- **Habitat Restoration:** Restoring degraded areas through replanting native vegetation, removing invasive species, and improving water quality.
- **Sustainable Management:** Implementing practices like responsible fishing, responsible aquaculture, and reduced pollution to minimize human impact.
- **Raising Awareness:** Educating communities about the importance of brackish water ecosystems and their vulnerability.
- **Empowering Local Communities:** Engaging local communities in conservation efforts, providing training, and promoting sustainable livelihoods.

Estuarine Ecosystem

An estuary is a geographical feature where a river or stream meets the sea, forming the mouth of the river.

Differences between Lagoon and Estuary

A lagoon refers to a shallow expanse of water shielded from a larger body of water, typically the ocean, by natural features like sandbars, barrier islands, or coral reefs. A lagoon and an estuary are both bodies of water with unique characteristics, **but they differ in their formation, location, and ecological features:**

Feature	Lagoon	Estuary
Definition	Saltwater body separated by sandbank or coral reef	Meeting point of river and sea with mixing water
Example	Backwaters in Kerala	Konkan Coast
Water Flow	Sluggish	Fast and Strong
Depth	Shallower	Usually Deeper
Freshwater Source	Generally Absent	Usually Present
Salinity	Higher	Lower
Formation	Due to falling sea levels (coastline emergence)	Primarily due to rising sea levels (coastline submergence)

India Estuarine Ecosystem

- **Abundance of Rivers:** India boasts a network of rivers, with 14 major, 44 medium, and 162 minor rivers emptying into the sea through various estuaries.
- **Concentration in Bay of Bengal**: The Bay of Bengal houses many major estuaries, which often serve as locations for significant seaports.
- **Regional Disparity:** India's major estuaries are predominantly situated along the east coast, while those on the west coast tend to be smaller. (Note: In environmental studies, deltas are considered subsections of estuaries).
- **Examples:** Two notable estuaries on the west coast are the Mandovi and Zuari estuaries.

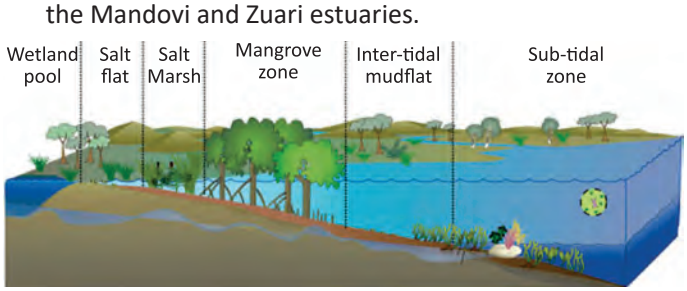


Fig. 3.8: Estuarine Ecosystem

Estuarine Ecosystem Characteristics

- **Nature of Estuaries:** Estuaries are partially enclosed coastal areas characterized by brackish water, with salinity levels ranging from 0.5 to 30 given above parts per thousand (ppt). They have one or more rivers or streams flowing into them and are connected freely to the open sea.
- **Mixing of Waters:** Freshwater carrying fertile silt and runoff from the land merges with the salty seawater in estuaries.
- **Transitional Zone:** Estuaries serve as transitional zones, known as ecotones, bridging river and maritime environments.
- **Variety of Forms:** Estuaries can take various forms, including river mouths, coastal bays, tidal marshes, lagoons and deltas.
- **Formation Processes**: Estuaries are formed due to factors such as rising sea levels, movement of sand and sandbars, glacial processes, and tectonic activity.
- **Adaptations to Salinity:** Plants and animals in estuaries have adaptations to cope with variations in salinity through osmoregulation.
- **Tidal Influence:** Estuaries are heavily influenced by tidal action, being periodically inundated by seawater once or twice daily, depending on tidal patterns.

Estuarine Ecosystem Flora and Fauna

- **Adaptation:** Only specific plant and animal species adapted to brackish estuarine waters thrive.
- **Aquatic Life:** Estuaries are habitats for diverse terrestrial and aquatic plants and animals, including wood storks, pelicans, sea turtles, sea lions, saltworts, eelgrass, and various grass species.
- **Phytoplankton Composition**: Phytoplankton in estuaries mainly consist of diatoms, dinoflagellates, green algae, and blue-green algae.
- **Variety of Vegetation Zones:** Large algae and seagrasses are found towards the sea coast, while mangrove forests are prevalent near river mouths and deltas.

Importance of Estuaries

- **Productivity:** Estuaries rank as the most productive water bodies globally, surpassing even wetlands. This heightened productivity stems from the blending of freshwater and saline water, facilitating the convergence of marine organisms from both ecosystems.
- **Ecotone Diversity:** Ecotone regions, including mangroves, wetlands, and estuaries, exhibit significantly greater productivity compared to individual ecosystems like forests, oceans, or deserts. This is attributed to the diverse species from adjacent ecosystems present within the ecotone.
- **Protective Shelter:** Due to minimal wave action, estuaries offer a tranquil refuge from the open sea, creating an ideal habitat for various aquatic species.
- **Nutrient Recycling:** Estuaries play a crucial role in storing and recycling nutrients, as well as trapping sediment, thereby forming a protective buffer between coastal catchments and marine environments.
- **Port Construction:** Due to their depth and protection from marine transgressions, estuaries serve as ideal locations for constructing ports and harbors.
- **Human Settlements and Waste Disposal:** The banks of estuarine channels are favored sites for human settlements, historically utilized for fishing and commerce. However, contemporary practices include the disposal of municipal and industrial waste into estuaries.

Issues and Challenges Faced by Estuarine Ecosystem

- **Altered Water Flow:** Changes in water flow within various estuaries, such as the Hooghly, Godavari and Pulicat, occur due to modifications in estuarine catchments, leading to either excessive or insufficient flow.
- **Pollution Sources:** Pollution from industrial activities and combined city sewage discharge poses a significant threat to Indian estuarine ecosystems.
- **Navigation and Shipping Impact:** Navigation, dredging and shipping activities, notably in places like the Hooghly, have adverse effects on estuarine ecosystems.
- **Urban and Industrial Expansion**: The expansion of urban and rural settlements, mining, industrial activities, agriculture, and solid waste dumping further exacerbate estuarine ecosystem issues.
- **Fish Stock Depletion**: Increased demand leads to the overexploitation of target fish stocks in estuarine regions.

Way Forward

- **Catchment Management:** Implement integrated river basin management in crucial estuaries like Pulicat Lake, incorporating measures like buffer zones and restrictions on unsustainable agricultural practices.
- **Pollution Abatement:** Enforce stricter industrial effluent standards and invest in advanced wastewater treatment plants, like the Nam Vanjyothi Sewage Treatment Plant in Mumbai. Promote initiatives like **Namami Gange** to tackle river pollution impacting downstream estuaries.
- **Responsible Recreation:** Implement designated boating zones and speed limits in sensitive areas like the Sundarbans, alongside educating tourists on responsible behavior and waste management.
- **Fisheries Management:** Implement science-based quotas and gear restrictions in collaboration with local fishing communities, like the successful co-management model employed in Chilika Lake.

The Estuarine Ecosystem offers valuable advantages and functions that greatly enhance our quality of life. These areas serve vital roles in nature, serving as habitats, breeding grounds, filters for water, flood regulators, and highly

productive ecosystems. Estuaries represent a distinct and precious natural asset that requires thoughtful management to ensure the collective well-being of all those who depend on and appreciate them.

Salt Marshes

Salt marshes represent coastal wetlands **subject to regular tidal flooding and draining**. Positioned between land and sea, they constitute distinctive ecosystems **consisting of a blend of grasses, sedges, rushes, and other vegetation** capable of thriving in saline environments.

Characteristics

- Salt marshes have a marshy texture due to the presence of soil consisting of deep mud and peat, with peat formed from decomposing plant matter that can accumulate to several feet in thickness.
- The characteristic sulfurous **rotten-egg odor emanates** from salt marshes. This odor **results from the frequent tidal** submersion of salt marshes and the abundance of decomposing plant material, leading to very low oxygen levels within the peat, a condition known as hypoxia.

Significance of Salt Marshes

- **Coastal Defense:** Salt marshes serve as the natural guardians of coastal areas, safeguarding the health of fisheries, shorelines, and communities.
- **Aquatic Habitat:** They act as vital habitats for various aquatic species by providing refuge, sustenance, and nursery areas for coastal fishery species like shrimps, crabs and numerous types of finfish.
- **Erosion Shield:** Salt marshes act as a protective barrier against shoreline erosion by mitigating the impact of wave action and by trapping sediment.
- **Flood Protection:** In regions prone to flooding, salt marshes mitigate flood risk by slowing the flow of floodwaters and absorbing excess rainfall.
- **Water Quality Preservation:** They play a crucial role in maintaining the water quality of coastal bays, sounds, and estuaries by filtering runoff and excess nutrients.
- **Carbon Storage:** Salt marshes, along with other coastal wetlands, function as essential **"carbon sinks,"** storing carbon that would otherwise be released into the atmosphere, thus helping to mitigate climate change.

Challenges

- Despite their array of benefits, salt marshes confront several threats jeopardizing their existence, with **sea level rise** emerging as one of the most significant challenges. As sea levels elevate due to climate change, salt marshes face the peril of **submersion and potential extinction**.
- Another menace to salt marshes arises from the **excessive introduction of nitrogen, which can disrupt the balance of plant species** and result in biodiversity loss. Sources of this surplus nitrogen encompass fertilizer runoff from agricultural lands and urban areas.
- Human activities, such as the **erection of seawalls and other coastal structures, can impede the natural landward migration of salt marshes** in response to rising sea levels. This phenomenon, termed **"coastal squeeze,"** confines the marshes between encroaching seas and man-made barriers.

Initiative Taken for Conservation

- The **Central Pollution Control Board (CPCB)** monitors water quality and implements regulations to reduce industrial and agricultural pollution impacting coastal areas.
- The **National Adaptation Fund for Climate Change (NAFCC)** supports projects like mangrove restoration and coastal embankment strengthening to address climate risks to Indian salt marshes.
- The **"Save Wetlands" campaign by WWF-India** raises awareness about wetland conservation and engages communities in restoration projects, including salt marsh protection.
- The **Pichavaram Mangrove Forest conservation project** involves local communities in mangrove restoration and sustainable fishing practices, indirectly benefiting nearby salt marshes.

Way Forward

- **Restore Degraded Marshes:** Conduct restoration projects to replant native vegetation, remove invasive species, and improve water quality.
- **Manage Human Activities:** Implement regulations and best practices to minimize pollution, overfishing, and other harmful activities.
- **Financial Support:** Mobilize resources from governments, international organizations, and private investors for conservation and restoration.
  - **Example:** The Global Environment Facility (GEF) provides funding for projects that protect and restore coastal ecosystems, including salt marshes.
- **Blue carbon projects:** Protect and restore marshes to promote carbon sequestration and combat climate change.

MARINE ECOSYSTEMS

Marine ecosystems are the largest of the Earth's aquatic ecosystems. They are defined as bodies of water with a salt concentration equal to or greater than that of seawater (i.e., Approx. 35 ppt or above). Marine waters occupy more than 70% of the Earths surface, constituting more than 97 percent of the planet's water and 90 percent of habitable space.

- The marine ecosystem encompasses the interplay between living (plants and animals) and non-living (inanimate) entities within marine environments.
- **Interdependence:** Each living organism within the marine ecosystem relies on others, establishing a food chain that sustains marine life.
- **Equilibrium Maintenance:** Both biotic (living) and abiotic (non-living) elements contribute to preserving an optimal balance within the ecosystem.
- **Contrast with Freshwater Ecosystems:** Marine ecosystems differ from freshwater ecosystems primarily due to the higher salt content found in marine environments.
- Marine ecosystem include the **open ocean, the deep-sea ocean, and coastal marine ecosystems,** each of which has different physical and biological characteristics.

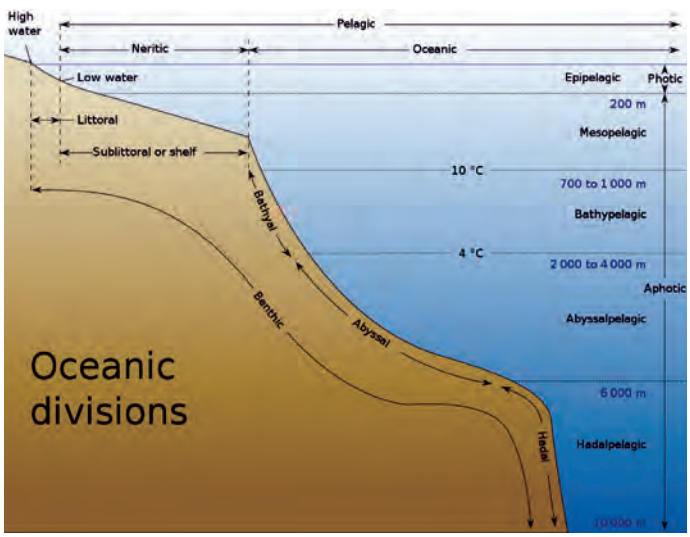


Fig. 3.9: Oceanic Divisions

Ocean water column is divided into five zones based on depth and light:

- **Epipelagic zone:** Also known as the sunlight zone, this layer extends from the surface to 200 metres.
- **Mesopelagic zone:** Also known as the twilight zone, this layer extends from 200 to 1,000 metres.
- **Bathypelagic zone:** Also known as the midnight zone, this layer extends from 1,000 to 4,000 metres.
- **Abyssopelagic zone:** Also known as the abyssal zone, this layer extends from 4,000 to 6,000 metres.
- **Hadopelagic zone:** Also known as the hadal zone, this layer extends from 6,000 metres and deeper.

- **Littoral Zone:**
  - **Definition:** The shallow area near the shore where sunlight penetrates to the bottom, allowing for the growth of rooted plants.
  - **Example:** The area along the edges of a lake or pond where you find emergent plants like cattails.
- **Limnetic Zone:**
  - **Definition:** Open water away from the shore, where sunlight penetrates, supporting photosynthesis by phytoplankton.
  - **Example:** The central region of a lake where sunlight reaches sufficient depths for the growth of algae.
- **Profundal Zone:**
  - **Definition:** The deep, dark area of a lake or pond where sunlight cannot penetrate, preventing photosynthesis.
  - **Example:** The bottom of a deep lake beyond the reach of sunlight, inhabited by organisms adapted to low light conditions.
- **Benthic Zone:**
  - **Definition:** The bottom layer of a body of water, including the sediment surface and sub-surface layers.
  - **Example:** The muddy or sandy bottom of a river or ocean floor where benthic organisms like worms and crustaceans reside.

IGNITE YOUR MIND

Oceans of Mystery: Revealing the Secrets of the Marine Realm

The extensive oceans envelop over 70% of the Earth's surface, concealing a hidden world of wonder. Explore the varied marine organisms, from microscopic plankton to majestic whales, and their intricate interactions within the ecosystem. What challenges and adaptations do marine organisms face in this vast and ever-changing environment?

Characteristics of Marine Ecosystem

- **Sunlight:** Sunlight plays a critical role in marine ecosystems, with habitats categorized into euphotic, dysphotic, and aphotic zones based on light availability. The euphotic zone, near the surface, supports abundant marine life due to ample sunlight for photosynthesis.
- **Temperature:** Marine water temperature fluctuates depending on geographical position, with equatorial regions experiencing warmer temperatures and polar regions colder ones. These temperature variations significantly impact species survival and adaptation.
- **Climate:** Marine ecosystems span a wide range of climates, from tropical to polar regions, and include additional climate types such as monsoon, subtropical, temperate, and subpolar climates.
- **Flora:** Plant species within marine ecosystems, including kelp, red algae, sargassum, and mangroves, play crucial roles as food sources and in oxygen and carbon dioxide exchange.

- **Fauna:** Marine ecosystems boast vast diversity, ranging from marine viruses to Blue Whales, the largest mammals. Besides well-known species like Dolphins, Whales, and Sharks, other animals such as Banded Sea Kraits, Leatherback Turtles, and Hawksbill Turtles inhabit these ecosystems.

Services Provided By Marine Ecosystems

Ecosystem services (ES) encompass ecological functions and economic value contributing to human well-being. Deep-sea ecosystem services (DSES) are crucial yet underexplored, constituting 97% of the ocean's volume.

- **Provisioning Services:** Tangible benefits including food, clean water, fuel and genetic resources. **Examples:** Fish, shellfish, seaweed, transportation, energy, minerals, and medicine.
- **Regulating Services:** Essential functions like air and soil quality maintenance, flood control, and climate regulation. **Examples:** Climate moderation, coastal protection, water purification, and biodiversity support.
- **Cultural Services:** Non-material advantages such as recreation, aesthetics, spiritual values, and education. **Examples:** Swimming, surfing, cultural identity, spiritual significance, and research opportunities.
- **Biodiversity Powerhouses:** Home to an incredible diversity of life, from microscopic plankton to giant whales, encompassing an estimated 90% of Earth's species. This diversity maintains ecosystem balance and provides resilience against environmental changes.
- **Climate Regulators:** Oceans absorb about 25% of human-produced carbon dioxide, mitigating climate change impacts. Phytoplankton in marine ecosystems produce oxygen, essential for all life on Earth.
- **Economic Powerhouses:** Provide food security through fisheries and aquaculture, supporting millions of livelihoods globally. Support maritime industries like shipping, tourism, and recreation, generating significant economic benefits.
- **Interconnectedness:** Marine ecosystems are not isolated; they are connected to all other ecosystems on Earth through water cycles, climate patterns, and migratory species. Their health directly impacts the health of our planet and all its inhabitants.
- **Biogeochemical Cycles in the Marine Environment:** It is the transfer of chemical components through processes like photosynthesis or chemosynthesis. Components are transferred to animals and detritus after organism death. Detritus becomes nutrients, upwelling restarts the cycle.
- **Ocean as Carbon Sinks:** Reservoirs that absorb atmospheric carbon through physical and biological mechanisms.
  - **Physical Pump:** Downward flow of water carrying dissolved carbon, especially in Polar Regions. It is less sensitive to disturbances but challenging to halt.
  - **Biological Pump:** Transfers surface carbon to the seabed through the food web for long-term storage. Vulnerable to disturbances and ecosystem-dependent, especially in high seas.
- **Ocean- Major Source of Oxygen:** Approximately half of Earth's oxygen is generated by the ocean. Oceanic plankton, including plants, algae, and bacteria, are responsible for oxygen production. Prochlorococcus, the smallest photosynthetic organism, contributes significantly.Ocean produces equivalent oxygen to all land plants. Primary producers in the ocean are more efficient than land plants. Oxygen generation is restricted to the upper, well-lit layer, reaching about 100 meters in depth. Stable density layering isolates the upper layer from the deeper ocean.
- **Marine Bioprospecting for Genetic Resources:** It is the systematic exploration of marine organisms for valuable biological resources. It encompasses microorganisms, sea plants, shellfish, and fish.
- **Marine Bioresources in Pharmaceuticals:** Marine biomes are rich in unique life systems for synthesizing bioactive compounds. Pharmaceutical sector actively expanding inventory of bioresource-based drugs.
- **Bioprospecting Phases and Interconnected Components:** It involves four crucial phases: sample collection, isolation, characterization, and product (drug) development and commercialization. It's a complex process where various components, including the owner(s) of marine genetic resources, bioprospectors, research and development groups, and end-product users, are interdependent.

Maritime transport vital for global trade, contributing to economic activities. Challenges include Greenhouse gas emissions and expected tripled maritime trade volumes by 2050.

Threats and Challenges Faced by Marine Ecosystem

Overfishing, habitat loss, exotic species introduction, ocean pollution, acidification, and warming are all threats caused by human activities in marine ecosystems.

- **Human-induced threats:** Overfishing, habitat loss, exotic species introduction, ocean pollution, acidification, and warming.
- **Alterations in Marine Species:** Changes in geographical range, seasonal activities, and biogeochemical alterations affecting oxygen levels.
- **Decline of Wilderness Areas:** Only about 13% of ocean area classified as wilderness, primarily in open ocean regions.
- **Ecosystem Impact on Marine Life:** Temperature changes influencing distribution, behavior, migration patterns, and reproductive timing of marine species.
- **Shifts in Fish Distribution:** Changes in sea temperature affecting physiology, behavior, and distribution of fish species, impacting fisheries and ecosystems.

- **Coral Bleaching:** Warmer ocean temperatures leading to coral bleaching, loss of vibrant colors, and increased susceptibility to disease.
- **Disruption of Ecosystem Services:** Changes in temperature and salinity disrupting fisheries, nutrient cycling, and climate regulation with cascading effects on human societies.
- **Shifts in Marine Phenology:** Changes in temperature influencing timing of biological events, affecting predator-prey relationships and marine ecosystem functioning.
- **Sea Level Rise:** Warming ocean temperatures causing thermal expansion, contributing to global sea level rise with implications for coastal communities and ecosystems.
- **Changes in Ocean Currents:** Temperature and salinity gradients impacting ocean currents, influencing marine ecosystems, nutrient transport, and climate systems.
- **Intensification of Extreme Weather Events:** Warmer ocean temperatures fueling more powerful tropical cyclones and hurricanes, posing increased risks to coastal communities and ecosystems.
- **Weakening of Atlantic Meridional Overturning Circulation (AMOC):** Oceanographic reconstructions showing AMOC weakening, with predictions of further decline in the 21st century, impacting temperatures, sea-level rise, and productivity in the North Atlantic. Severe AMOC weakening could cause irreversible collapse, profoundly affecting marine and terrestrial ecosystems, temperatures, precipitation, agriculture, and extreme weather events.

Atlantic Meridional Overturning Circulation (AMOC)

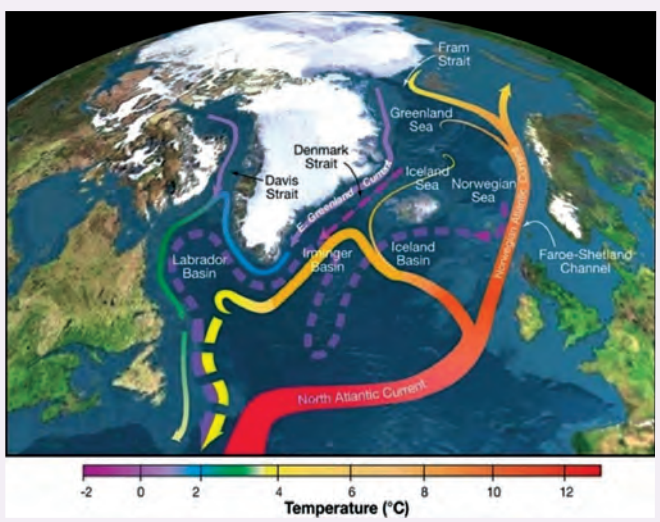


Fig. 3.10: Nordic Seas and Subpolar Basins with Surface Currents (Solid Curves) and Deep Currents (Dashed Curves) that form a Portion of the Atlantic Meridional Overturning Circulation.

- The **AMOC** is a component of global ocean thermohaline circulation, with northward warm surface flow and southward cold deep flow.
- **Climate change** poses a risk of **AMOC weakening** due to increased ocean heat and melting ice sheets.
- The **AMOC cycle** and **global conveyor belt** are slow, taking about 1,000 years for a water parcel to complete its journey.
- **AMOC** significantly influences the **global heat budget**, affecting **Western Europe's climate** and acting as a **carbon sink** to combat **global warming**.
- **Slowing & Weakening: IPCC** forecasts likely **AMOC weakening** in the 21st century, driven by a warming atmosphere, increased precipitation, and ice melt, reducing overall ocean density.
- **Consequences:** Anticipated impacts include reduced marine productivity, increased storms in Northern Europe, elevated sea levels along North America's northeast coast, decreased summer rainfall in the Sahel and South Asian region, and complex effects on the **Indian Ocean's climate** and salinity.

IGNITE YOUR MIND

Ocean Acidification: A Looming Threat

The delicate balance of marine ecosystems faces a new challenge: ocean acidification. Can the silent acidification of our oceans speak louder than words, urging us to reflect on the delicate balance of marine life and the urgent need for sustainable solutions?

Way Forward

- **Crafting a National Accounting Framework:** To evaluate the significance and consequences of the Marine Economy while formulating suitable policies and interventions.
- **Coastal and Marine Spatial Planning:** Enforcing planning strategies for coastal and marine areas to manage spatial allocation of resources and activities in a cohesive manner.
- **Bolstering Legal and Institutional Framework for Ocean Governance:** Strengthening frameworks to adhere to both domestic and international laws and regulations, safeguarding India's sovereignty, security, curbing unlawful activities, and resolving disputes.
- **Advancing Capacity and Technology for Marine Research and Innovation:** Supporting research and innovation in the marine domain to facilitate informed decision-making and unlock potential growth opportunities.

AQUATIC ORGANISMS

Aquatic Organisms Classification

Aquatic organisms are interconnected living beings that depend on each other within water-based habitats such as oceans, rivers, and various water bodies. They spend

their entire lives submerged in water and utilize specialized organs to extract oxygen from their surroundings. While **some absorb oxygen through their skin, others utilize gills for this purpose**.

Aquatic organisms are categorized into groups including **Neuston, Periphyton, Plankton, Nekton, and Benthos** based on their habitat and behaviour.

Neuston

Neuston, also known as pleuston, comprises organisms that inhabit the surface of various aquatic environments such as oceans, estuaries, lakes, rivers, or ponds.

Fig. 3.11: Neustons

- Coined by Naumann in 1917, the term **"neuston"** was introduced to classify organisms residing specifically in the surface layers of freshwater ecosystems.
- Neuston organisms can be **found not only on the upper surface of the water but also underneath it,** adapting to various microenvironments within aquatic systems.
- In addition to surface dwelling, neuston organisms may inhabit the surface microlayer, which forms between the upper and lower surfaces of the water.
- Neuston organisms **play essential ecological roles**, serving as a food source for zooplankton migrating from deeper layers to the surface, and also contributing to the diet of seabirds flying above the oceans.

Periphyton

Periphyton in aquatic ecosystems typically comprises a diverse blend of algae, cyanobacteria, heterotrophic micro-organisms and organic matter adhering to submerged surfaces.

Fig. 3.12: Periphyton

- Periphyton has **evolved to thrive specifically on hard surfaces** within aquatic environments.
- The growth of periphyton is **influenced by temperature,** which is often correlated with the absolute temperature range and stability in its habitat.
- Periphyton communities play a crucial role in **aquaculture food production system**s by aiding in the removal of solids and dissolved contaminants.

Plankton

Plankton constitutes a diverse array of organisms inhabiting water or air, characterized by their inability to actively swim against currents or winds.

- Plankters refer to the **individual organisms comprising planktonic communities**.
- Planktonic organisms exhibit a **wide size range**, spanning from as small as 0.2 micrometers to exceeding 20 centimeters in size.

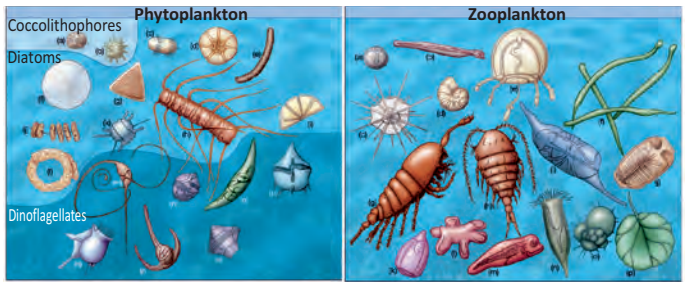


Fig. 3.13: Plankton

- The **distribution** of plankton varies based on factors such as light availability and nutrient levels, encompassing microscopic bacteria to large species like jellyfish.
- Plankton serves as a **vital food source for larger aquatic species**, highlighting their significance within marine ecosystems.

Nekton

Nekton, also known as swimmers, refers to living organisms capable of independent swimming and movement, unaffected by prevailing currents.

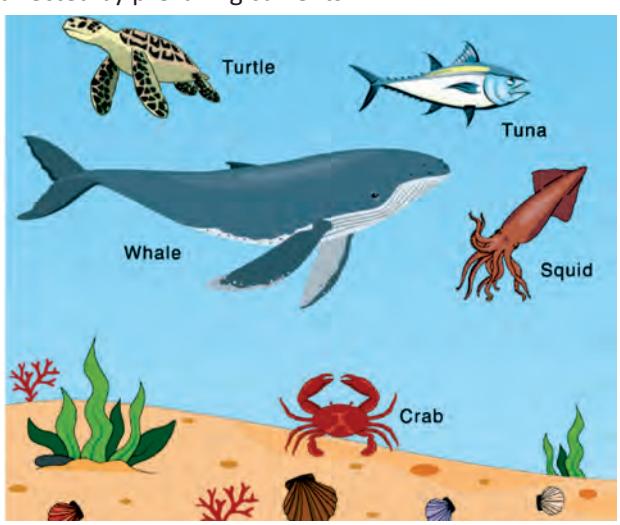


Fig. 3.14: Nekton

- The term "nekton" was **first introduced by German biologist Ernst Haeckel**, who used it to distinguish between actively swimming organisms and plankton, which are passively transported by currents.
- Nektonic organisms can **inhabit both the photic (well-lit) and aphotic (dark) zones** of aquatic environments.
- Within marine ecosystems, nekton plays a pivotal role as a **crucial link bridging primary consumers with higher trophic levels in food webs**.

Benthos

- The term "benthos" refers to the **group of organisms inhabiting, residing on, or closely adjacent to the bottom of various aquatic bodies**, including seas, rivers, lakes, or streams.
- The **benthic zone** encompasses the sediment surface and certain sub-surface layers, constituting the ecological region situated at the lowest level of water bodies such as oceans, lakes, or streams.

- Among benthic organisms, **macrobenthos**, which measures greater than 1 mm, has garnered the most extensive research attention to date.
- Benthic creatures can be **categorized into two groups based on their habitat preference**: those dwelling directly on the ocean floor and those residing a few centimeters below its surface.

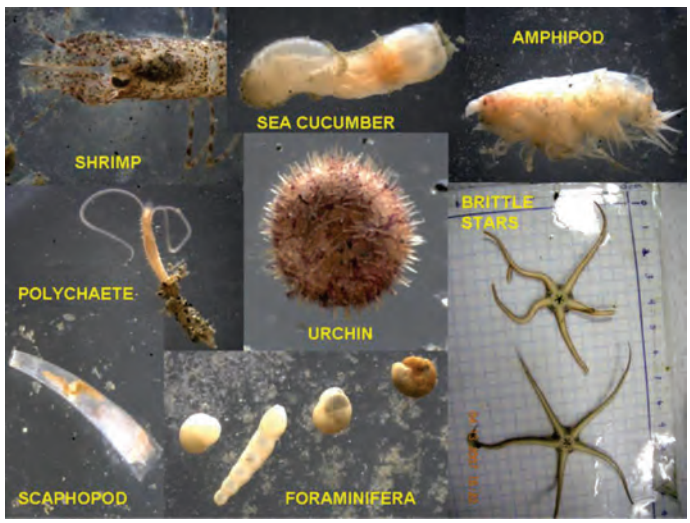


Fig. 3.15: Benthos

Marine Food Sources	Examples
Finfish	Small pelagic fish (herring, sardines, anchovies); Medium pelagic fish (bonito, mahi-mahi); Large pelagic fish (tuna, swordfish) Salmonids (salmon, trout); Carps; it is freshwater fish Cods (cod, haddock, pollock); Demersal fish (flounder)
Crustaceans	Crabs; Shrimp; Krill; Prawns; Lobster
Cephalopods	Octopus & Squid
Mollusks	Clams; Cockles; Sea snails; Mussels; Scallops
Aquatic Plants	Water spinach (Ipomoea aquatica)
Algae	Seaweed
Other Aquatic Animals	Mammals; Insects; Sea cucumbers

In conclusion, every aquatic organism, whether it's a bacterium or a blue whale, possesses its own unique characteristics. It is the genetic makeup, rather than the size, that sets apart each life form. Our dependence on a multitude of aquatic plants and animals, along with their ecological functions, is crucial for our existence. The absence of this diverse array of aquatic organisms would result in a diminished quality of life, restricted availability of medications, fewer career prospects, and a less robust economy.

IGNITE YOUR MIND

Tiny Titans: Examining the Crucial Role of Plankton in Aquatic Food Webs

Meet the microscopic powerhouses of the oceans, namely phytoplankton and zooplankton. How do these seemingly insignificant organisms play a vital role in the marine food web, global climate, and the health of aquatic ecosystems?

AQUATIC VEGETATION

Aquatic plants, diverse in their forms and functions, play a crucial role in maintaining the health of water ecosystems. They provide essential services for aquatic life by offering:

- **Habitat:** A heaven for diverse organisms, from microscopic invertebrates to large fish, seeking shelter, breeding grounds, and nursery areas.
- **Food:** From tiny algae to emergent grasses, aquatic vegetation forms the base of the food chain, nourishing a wide range of creatures.
- **Oxygen:** Through photosynthesis, submerged plants release oxygen that is vital for aquatic respiration, keeping the ecosystem thriving.

These underwater wonders can be categorized based on their unique growth habits and preferred environments:

- **Submerged Plants:** Anchored in the sediment, these plants thrive entirely underwater, some reaching the surface with leaves or flowers.
  - **Examples** include eelgrass, Canadian pondweed, and hornwort. They oxygenate the water, provide food and shelter, and stabilize sediments.
- **Emergent Plants:** Rooted in the bottom, these plants rise above the water's surface, often found along shorelines.
  - **Examples** include cattails, bulrushes, and reeds. They combat erosion, offer breeding grounds and shelter, and filter pollutants.
- **Floating Plants:** These plants either have roots dangling in the water or are completely free-floating. They provide shade, limit algae growth by reducing sunlight penetration, and offer habitat for aquatic life.
  - **Examples** include water lilies, lotus (rooted), and duckweed, water hyacinth (free-floating).
- **Marginal Plants:** Growing at the water's edge, these plants can survive both submerged and in wet soil. They filter runoff, stabilize shorelines, and provide habitat for various wildlife.
  - **Examples** include pickerelweed, arrowhead, and Japanese iris.

- **Algae:** Ranging from microscopic phytoplankton to large seaweeds, algae lack true roots, stems, or leaves. They are the primary producers, forming the base of aquatic food webs and oxygenating the water, making them crucial for ecosystem health.
    - **Examples** include green algae, blue-green algae, and brown algae.

Each type of aquatic vegetation plays a unique and vital role in maintaining healthy water ecosystems. They support biodiversity, improve water quality, and provide essential services that ensure the thriving of aquatic life.

Seaweed, and seagrass are often found in marine environments and play important roles in their respective ecosystems. Understanding and appreciating their unique contributions is crucial for preserving the blue world's biodiversity and resilience.

Sea-Grass

Seagrass is a flowering plant that grows entirely underwater in shallow, sandy coastlines. Seagrass is the only plant that can live completely submerged under water.

Characteristics of Seagrasses

- **Distribution in India:** Significant seagrass meadows are found along the southeast coast of Tamil Nadu and within the lagoons of select Lakshadweep Islands. Sparse grass beds also exist around the Andaman and Nicobar Islands.
- **Botanical Nature:** Seagrasses, classified as angiosperms, are marine flowering plants that bear resemblance to terrestrial grasses in appearance.
- **Physical Attributes:** These plants feature strap-like or oval leaves and possess a root system typical of terrestrial plants.

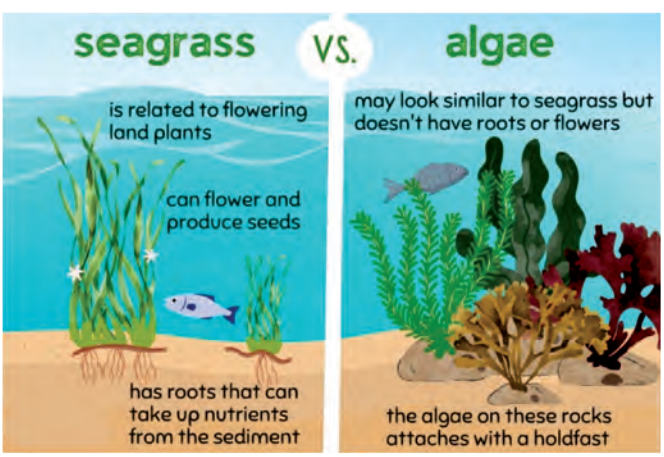

seagrass
VS.
algae
is related to flowering land plants
can flower and produce seeds
has roots that can take up nutrients from the sediment
may look similar to seagrass but doesn't have roots or flowers
the algae on these rocks attaches with a holdfast

Fig. 3.16: Seagrass vs Algae (Seaweed)

- **Habitat Requirements:** Seagrasses thrive in shallow coastal waters characterized by sandy or muddy bottoms. They typically prefer relatively calm areas for optimal growth.
- **Adaptation to Saltwater:** Remarkably, seagrasses are the sole group of higher plants uniquely adapted to life in saline environments, thriving in saltwater habitats.

Functions

- **Wave and Current Reduction:** Seagrass beds serve as natural barriers, effectively diminishing wave and current energy, thereby mitigating coastal erosion.
- **Sediment Filtration:** The dense root systems of seagrasses filter suspended sediments from the water column, enhancing water clarity and quality.
- **Habitat Provision:** Seagrass beds provide vital habitat for a diverse array of marine invertebrates and fish species, offering refuge, breeding grounds, and foraging areas.
- **Enhanced Biodiversity:** Areas with extensive seagrass beds, such as lagoons, support higher populations of fish and migratory birds due to the abundance of food and shelter provided by the seagrass habitat.
- **Nutrient Sink Function:** Seagrasses located on reef flats and near estuaries act as nutrient sinks, buffering and filtering nutrient and chemical inputs into the marine environment, thereby contributing to overall ecosystem health and balance.

IUCN Conservation Priority for Seagrass

- **Recognition of Importance:** The **International Union for Conservation of Nature (IUCN)** has designated seagrass conservation as a high priority due to its ecological significance.
- **Species Diversity in India:** Among the 58 seagrass species worldwide, India harbors fourteen recorded species along its coastlines.
- **Depth and Distribution:** Seagrasses are commonly distributed across a range of habitats, from inter-tidal zones to sub-tidal regions, extending to depths of up to 8 meters.
- **Threat to Dugong Population:** Dugongs, marine mammals reliant on seagrass as their primary food source, face a critical threat of extinction due to habitat loss and degradation of seagrass ecosystems.

Seaweeds

Seaweeds are **multicellular, marine algae that are not actually plants**, despite their appearance. They come in a **variety of colors, shapes, and sizes,** and can be found growing in the ocean all over the world. They play a vital role in the marine ecosystem, providing food and habitat for many other organisms.

Characteristics of Seaweeds

- **Thalloid Structure:** Seaweeds, classified as macroscopic algae, lack true tissue differentiation such as roots, stems, and leaves. Instead, they possess leaf-like appendages.

- **Habitat:** These larger, visible marine plants are commonly found attached to rocks, corals, and other submerged structures within the intertidal and shallow subtidal zones of the sea.
- **Preference for Shallow Coastal Waters:** Seaweeds thrive in shallow coastal waters wherever substantial substrates are available for attachment and growth.
- **Classification Based on Pigmentation:** Seaweeds are broadly categorized into various classes based on the color of their pigmentation, including blue-green, green, brown, red, and others.

Fig. 3.17

Seaweed vs Seagrass vs Kelp vs Algae

In this comparison, we delve into the distinct characteristics of seaweed and seagrass, highlighting their structural differences, ecological roles, and practical applications.

Characteristic	Seaweed	Seagrass	Kelp	Algae
Classification	Protists or multicellular algae	Flowering plants	Large brown algae	Diverse group, including micro and macro forms
Structure	Multicellular, simple structures	Flowering plants with roots, stems, leaves	Large brown algae with holdfasts, stipes, blades	Varies from simple to complex structures
Attachment	Attached by holdfast	Roots anchor in sediment	Attached by holdfast	Can be free-floating or attached
Size	Varies from small to large	Small to large, species-dependent	Large, up to 60 meters	Microscopic to macroscopic
Habitat	Marine environments, attached	Submerged in coastal areas	Subtidal in cold, nutrient-rich waters	Wide range, freshwater to marine, attached or free-floating
Ecological Role	Habitat, food, oxygen production	Nursery areas, sediment stabilization	Habitat, food, supports marine life	Roles in oxygen production, nutrient cycling
Commercial Use	Food source, industrial applications	Limited commercial use	Food, supplements, cosmetics	Various uses like food additives, bio-fuels, pharmaceuticals
Example	Nori, Kelp, Dulse	Eelgrass, Turtle grass	Giant kelp, Bull kelp	Green algae, Red algae, Brown algae

Functions and Uses of Seaweeds

- **Primary Producers:** Like land plants, seaweeds use photosynthesis to capture sunlight and convert it into energy. They are the foundation of the marine food chain, providing nourishment for countless creatures, from tiny herbivores to large fish.
- **Habitat Architects:** Seaweed forests create complex underwater structures that provide shelter and breeding grounds for a wide variety of marine life. From the towering fronds of kelp to the intricate branches of red algae, these underwater havens are essential for maintaining biodiversity.
- **Nutrient Cyclers:** Seaweeds absorb dissolved nutrients from the water and release them back into the environment through decomposition. This nutrient cycling is crucial for maintaining the overall health and productivity of the marine ecosystem.
- **Carbon Sequestration:** Seaweeds, like their land-based counterparts, act as carbon sinks, absorbing carbon dioxide from the atmosphere and storing it in their tissues. This helps to mitigate the effects of climate change.
- **Medicinal Applications:** Seaweeds have medicinal properties and are employed in the treatment of conditions such as goiter, intestinal disorders and stomach ailments.
- **Commercial Products:** Valuable commercial products like agar-agar, alginates and iodine are extracted from seaweeds, contributing to various industries.

Harmful Effects of Seaweeds

- **For Humans:**
  - **Toxicity:** Certain seaweed species can accumulate toxins from the environment, making them unsafe for consumption. This depends on the specific species, location and environmental factors. Proper identification and responsible sourcing are crucial.
  - **Allergic Reactions:** Some individuals may experience allergic reactions to specific seaweed components, leading to skin irritation, digestive issues, or respiratory problems.

- **Excessive Iodine Intake:** Some seaweeds are particularly high in iodine, which can be harmful in excessive amounts, leading to thyroid issues for individuals with pre-existing conditions. Moderation is key.

❑ **For the Environment:**

- **Habitat Destruction:** Unsustainable harvesting practices can damage seaweed populations and the delicate ecosystems they support. Responsible harvesting and aquaculture are essential.
- **Introduction of Invasive Species:** Cultured seaweed varieties can escape into the open ocean, potentially outcompeting native species and disrupting local ecosystems. Careful management of aquaculture practices is crucial.
- **Nutrient Pollution:** Improperly managed seaweed farms can contribute to nutrient overload in coastal waters, leading to algal blooms and other environmental problems. Sustainable farming methods are necessary.

Way Forward

❑ The disappearance of seagrass habitats could lead to the extinction of marine organisms reliant on them, ultimately diminishing productivity within marine ecosystems.

❑ Implementing protection and restoration efforts on a global scale could substantially contribute to alleviating climate change.

❑ Urgent actions are imperative to conserve seagrasses and their habitats. The **International Union for Conservation of Nature (IUCN)** should promptly intervene to assess the status of various seagrass species before they reach extinction.

Important Types of Algae

Type of Algae	Characteristics	Habitat	Examples	Importance
Green Algae (Chlorophyta)	Chlorophyll dominant pigment, Unicellular, colonial, or multicellular, Freshwater and marine environments, Cell wall made of cellulose	Freshwater and marine	Chlamydomonas, Spirogyra, Ulva	Base of aquatic food webs, Important for oxygen production, Used in biofuels and wastewater treatment
Red Algae (Rhodophyta)	Phycobilins as accessory pigments, Unicellular, multicellular, or filamentous, Primarily marine, Cell wall made of agar or carrageenan	Marine	Gracilaria, Porphyra, Corallina	Source of agar and carrageenan (food thickeners), Important for coral reef health, Used in cosmetics and pharmaceuticals
Brown Algae (Phaeophyceae)	Fucoxanthin as accessory pigment, Multicellular with complex structures, Mostly marine, Cell wall made of algin	Mostly marine	Fucus, Laminaria, Sargassum	Important for coastal ecosystems, Used in food and fertilizers, Source of alginate (thickener)
Diatoms (Bacillariophyceae)	Silica frustules as cell walls, Unicellular or colonial, Freshwater and marine	Freshwater and marine	Diatoma, Cyclotella, Navicula	Major contributors to phytoplankton, Important for oxygen production and carbon sequestration, Used in industrial applications like filtration
Yellow-green Algae (Xanthophyceae)	Chlorophyll and carotenoids as pigments, Unicellular or colonial, Freshwater and marine, Cell wall made of cellulose	Freshwater and marine	Vaucheria, Tribonema, Botryococcus	Important for nutrient cycling, Used in aquaculture and biofuels research
Dinoflagellates (Dinophyceae)	Dinokaryotic cells with flagella, Mixotrophic or heterotrophic, Freshwater and marine, Can form harmful algal blooms (HABs)	Freshwater and marine	Alexandrium, Gonyaulax, Noctiluca	Important part of marine food webs, Some species produce toxins causing HABs, Used in bioluminescence research
Euglenoids (Euglenophyta)	Mixotrophic or heterotrophic, Unicellular with flagella, Freshwater and terrestrial, Can move with flagella	Freshwater and terrestrial	Euglena, Phacus, Trachelomonas	Important for nutrient cycling in freshwater ecosystems, Some species are parasites
Golden Algae (Chrysophyceae)	Chlorophyll and carotenoids as pigments, Unicellular or colonial, Freshwater and marine, Mixotrophic or heterotrophic, Silica scales on cell wall	Freshwater and marine	Ochromonas, Synura, Mallomonas	Important part of freshwater food webs, Some species are parasites

AQUACULTURE

Aquaculture refers to the **artificial cultivation of aquatic organisms**, including plants and animals. Its **primary purpose is to rear commercially valuable species** such as freshwater and marine fish, mollusks, crustaceans, and aquatic plants. While natural water bodies harbor diverse ecosystems, only a small fraction of species are harvested by humans.

Despite there being approximately 20,000 known fish species, only a select few, **around discuss of them, are extensively exploited by humans**. Fisheries involve the harvesting of food from **both marine and freshwater environments**, whereas aquaculture involves the cultivation of aquatic organisms in artificially created water bodies. Examples include the cultivation of fish like Carps and Tilapia.

There are two types of aquaculture:

Fish Farming

- Fish farming involves cultivating fish in a controlled environment, often within coastal or inland ponds, lakes, reservoirs or even rice fields (paddies).
- Fish are nurtured until they reach the desired size for harvesting.

Fish Ranching

- Fish ranching entails keeping young fish in captivity for initial years, typically within floating cages situated in coastal lagoons.
- These fish are later released into natural water bodies as adults.
- Adult fish are then harvested when they return to the lagoons for spawning, particularly significant for species like Salmon and Hilsa, which migrate to rivers for spawning and are cultivated using the fish ranching method.

Hope Spots

Hope Spots are a global network of marine protected areas **designated by Mission Blue**, a Non-profit organisation found by renowned oceanographer Dr. Sylvia Earle. These special places have been identified as **critical to the health of the ocean and hold promise for its restoration**.

What are they?

- Ecologically unique areas facing threats.
- Can be existing marine protected areas needing more attention or new sites requiring protection.
- Nominated by anyone who sees hope for a specific marine area.
- Supported by Mission Blue and a network of partners (scientists, NGOs, local communities).

Why are they important?

- **Protect Biodiversity:** Rich habitats for diverse marine life, providing vital nursery grounds and breeding areas.
- **Promote Healthy Oceans:** Enhance ecosystem resilience, improve water quality, and support fisheries sustainability.
- **Inspire Community Action:** Empower local communities to safeguard their marine resources and build sustainable livelihoods.
- **Raise Awareness:** Showcase the beauty and value of the ocean, highlighting the need for conservation.

Lakshadweep Islands

- **Location:** Union Territory in the Arabian Sea, consisting of 36 a islands with 12 atolls.
- **Significance:** Pristine coral reefs, unique biodiversity, important breeding grounds for seabirds and turtles.
- **Threats:** Climate change, plastic pollution, unsustainable fishing practices.
- **Hope Spot Efforts:** Sustainable tourism initiatives, community-based fisheries management, plastic waste reduction campaigns.

Andaman and Nicobar Islands

- **Location:** Archipelago in the Bay of Bengal, known for its pristine coral reefs and rainforests
- **Significance:** Globally significant biodiversity hotspot, home to endemic species and unique ecosystems.
- **Threats:** Invasive species, habitat loss, unsustainable tourism practices.
- **Hope Spot Efforts:** Coral reef monitoring and restoration, community-based tourism development, protected area expansion.

IGNITE YOUR MIND

A Beacon of Hope: Exploring Initiatives to Protect Aquatic Ecosystems

Embark on a journey through initiatives shaping the future of our oceans and freshwater systems. From global organizations like UNEP and IPCC to local endeavors, discover diverse efforts aimed at overcoming challenges. What initiatives inspire you, and how can we all play a part in safeguarding our precious water realms?

CONCLUSION

In conclusion, the health of aquatic ecosystems is vital for sustaining biodiversity and supporting human well-being. These ecosystems provide essential services such as water purification, flood control, and climate regulation. Human activities, including pollution, overfishing and habitat destruction, threaten the delicate balance of aquatic ecosystems. Conservation efforts must be prioritized to preserve these invaluable habitats and mitigate the impact of anthropogenic pressures. Through collaborative management and sustainable practices, we can safeguard aquatic ecosystems for future generations.

Wetlands, Mangroves and Corals

4

INTRODUCTION

Wetlands, mangroves, and coral reefs are critical ecosystems that filter water, defend coastlines, and support an incredible diversity of life, highlighting the critical need for worldwide conservation efforts in the face of challenges from **human activity and climate change.** In the environment, ecotones, or transitional zones between various ecosystems emerge as crucial for preserving ecological connectedness and health. They function as dynamic interfaces, increasing biodiversity and facilitating the passage of energy, nutrients and organisms that enrich adjacent habitats, and strengthen ecosystem resilience. Protecting the connected roles of wetlands, mangroves, coral reefs, and their ecotones is critical to maintaining the planet's ecological balance and the services these ecosystems offer.

ECOTONE

- Ecotones are the transitional zones between two biological communities, where two communities meet and integrate. Ecotones are crucial to the **connectivity and health** of many ecosystems, including wetlands, mangroves, and coral reefs.
- These transitional zones frequently serve as the **boundaries between terrestrial and aquatic ecosystems,** such as the borders of wetlands that merge into upland or marine areas.
- **Ecotones** can be found in wetlands where marshes meet grasslands or woodlands, improving biodiversity and ecosystem functions including water purification and flood control.
- **Mangroves,** which are commonly found near the land-sea border, are a distinct type of ecotone.
- They stand out for their capacity to thrive in salty coastal waters, creating a buffer zone to shield shorelines from storm surges and erosion. Mangrove tree roots trap sediments and pollutants, keeping them from reaching coral reefs, which are typically located further offshore.
- This interaction emphasises the role of ecotones in connecting different ecosystems and supporting a diverse range of species.
- **Upstream ecotones** such as mangroves and wetlands offer clean water and reduce sedimentation, which benefits coral reefs.
- These **coral ecosystems,** in turn, support a diverse range of marine species while protecting coastal areas from the full force of ocean waves.
- The **interconnection of ecotones,** wetlands, mangroves, and coral reefs demonstrates the intricate web of relationships that support these critical ecosystems.
- Understanding and protecting ecotones is critical for sustaining the health and resilience of wetlands, mangroves, and coral reefs, all of which are essential for biodiversity, climate control, and human well-being.

How are Wetlands, Mangroves, and Coral Reef Ecosystems Different from Other Ecosystems?

Wetlands, mangroves and coral reefs differ from other ecosystems due to their unique environmental circumstances, biodiversity, and ecosystem services.

- **Environmental Conditions:** The specific environmental conditions required for the existence of **wetlands, mangroves, and coral reefs**—such as water salinity, depth, and quality—are unique and create habitats that are distinct from terrestrial and other aquatic ecosystems.
- **Specialised Biodiversity:** These ecosystems support species that are specially adapted to their unique conditions, often not found in other habitats. This includes a range of **plants, animals, and microorganisms** that rely on the specific ecological characteristics of wetlands, mangroves, and coral reefs.
- **Ecosystem Services:** The services provided by these ecosystems, such as **coastal protection, water filtration, and carbon sequestration,** are critical to human well-being and environmental health, often surpassing those offered by other ecosystems in terms of their impact on global processes like climate regulation and biodiversity support.

WETLAND

Wetlands are complex ecosystems characterised by **soil flooding or saturation, resulting in low-oxygen environments that favour a specialised assemblage of plants, animals, and bacteria.** These species have traits that allow them to endure slow-moving or stationary water. Wetlands are often defined by soil and plant life as bogs, marshes, swamps, and other similar ecosystems. Wetland science and ecology have grown in popularity since the 1970s, owing to environmental legislation and regulations.

- The term **"wetland"** was first explicitly used in 1953, in a report by the U.S. Fish and Wildlife Service (USFWS) and has subsequently been defined in a variety of ways.
- The **Ramsar Convention defines** wetlands as areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including marine water with a depth of no more than six metres at low tide.
- According to **Wetlands (Conservation and Management) Rules 2017,** a "wetland" means an area or of marsh, fen, peatland or water; natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres and includes all inland waters such as lakes, reservoir, tanks, backwaters, lagoon, creeks, estuaries and manmade wetland and the zone of direct influence on wetlands that is to say the drainage area or catchment region of the wetlands as determined by the authority.

WETLAND ECOSYSTEM

- Wetlands are dynamic ecosystems characterised by the **presence of water, either seasonally or permanently, creating a unique environment that supports a diverse range of life.**
- These areas serve as crucial transition zones between terrestrial and aquatic ecosystems, harbouring the characteristics of both.
- The presence and depth of water in wetlands can vary seasonally, influencing the type of vegetation and wildlife that can thrive.

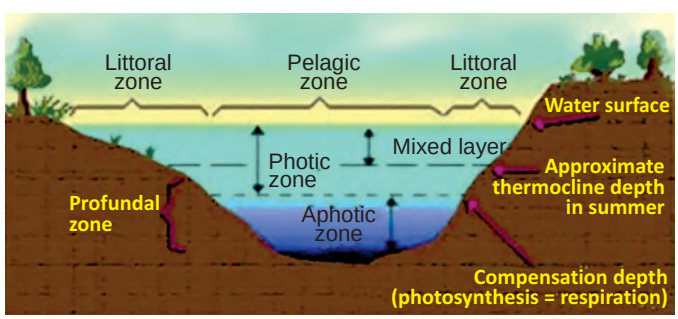


Fig. 4.1: Wetland Ecosystem

Features of Wetland Ecosystem

- **Hydrology:** Wetlands are saturated with water, sourced from **groundwater, rivers, lakes, or tides.**
- **Vegetation:** Adapted to **hydric soils,** wetland plants, known as **hydrophytes,** thrive in water-saturated conditions. The type of vegetation ranges from trees and shrubs in seasonally dry wetlands to mosses and grasses in areas that are frequently flooded.
- **Biodiversity:** Wetlands support a high diversity of species, provide habitat, breeding grounds and food sources for various aquatic and terrestrial organisms.

TYPES OF WETLANDS

Wetlands are among the **most productive** and ecologically vital habitats on the planet, providing a critical home for a diverse range of species, acting as natural water purifiers, and playing an important role in **carbon storage and flood control.** Their diversity is tremendous, with each species of wetland serving a particular role and supporting a diverse environment. Their types include:

Bogs

- Bogs are **acidic wetlands** characterised by spongy peat deposits, acidic waters, and a thick carpet of **sphagnum moss.**

Fig. 4.2: Types of Wetlands

- They develop in **cold, northern climates** and typically receive their nourishment from **precipitation rather than groundwater, making them nutrient-poor.**
- The water in bogs is acidic due to the accumulation of organic materials and the lack of nutrient inflow from groundwater.
- This environment supports a unique set of plant and animal life adapted to its acidic conditions. Plants such as **cranberries, blueberries,** and carnivorous species like **sundews and pitcher plants** are common in bogs.
- These wetlands play a crucial role in **storing carbon,** thus helping to mitigate climate change.
- **Example: Dheerpur Wetland Park, Delhi**

Fens

- Fens are **peat-forming wetlands** that, unlike bogs, receive nutrients from sources other than **precipitation,** mainly from **groundwater.**
- This influx of nutrients makes fens less **acidic than bogs,** supporting a wider variety of plant life.
- Fens are important for biodiversity, providing habitat for many rare and specialised species.
- They can be found **from the Arctic to the equator,** though their characteristics vary significantly with **local conditions.**

- Fens contribute to **water purification, flood mitigation, and carbon sequestration,** making them valuable ecosystems for environmental health and climate regulation.
- **Example: East Calcutta Wetlands, West Bengal**

Marshes

- **Herbaceous** plant species, rather than woody plant species, **predominate in marshes,** which are wetlands.
- They are typically found near the **edges of lakes and streams,** where they can form extensive networks.
- Marshes are divided into two main types: **Freshwater and saltwater (or tidal) marshes.**
  - **Freshwater marshes** are common in the interior of continents, where water levels fluctuate seasonally.
  - **Saltwater marshes** are present along coastlines, where tides have an impact on them.
- Marshes are highly productive ecosystems that provide critical habitat for a wide range of wildlife, including **migratory birds (like flamingos), fishes, and amphibians.**
- They also offer **flood protection** and act as **filters for pollutants,** improving water quality.
- **Example: Keoladeo National Park (Bharatpur Bird Sanctuary), Rajasthan**

Swamps

- **Woody plants,** like trees and shrubs, predominate in **swamps,** which are wetlands.
- They **often form in floodplains** along large rivers or in areas with high groundwater.
- Swamps can be divided into two main categories: **Freshwater swamps and saltwater swamps,** the latter of which are often found along **tropical and subtropical coastlines.**
  - **Freshwater swamps** are rich in biodiversity, providing habitat for a wide array of wildlife, including birds, reptiles, and mammals.
  - **Saltwater swamps,** such as mangrove forests, are crucial for protecting coastlines from erosion and storm surges.
- Swamps play an important role in **water purification and flood control,** and they significantly also act as carbon sinks.
- **Example: Sundarbans, West Bengal.**

IGNITE YOUR MIND

Wetland Wonders: Often dismissed as wastelands, wetlands burst with life, playing a vital role in our environment. From filtering water to preventing floods, these hidden gems offer surprising benefits. Dive in and discover the different types of wetlands and their crucial contributions.

Classification of Wetlands

Wetlands are dynamic ecosystems that vary widely in their forms, functions and interactions with the landscape. Beyond the basic types of wetlands, these ecosystems also exhibit different patterns and connections within the landscape, each with unique ecological characteristics.

On the Basis of Distinct Features

- **Lacustrine Wetlands**
  - Lacustrine wetlands are **associated with lakes and reservoirs,** typically characterized by **standing water** with little to no flow. These wetlands are found in depressions or between shorelines and deeper waters of lakes or reservoirs.
  - **Features:** They often support a variety of aquatic plants and animals adapted to still water conditions. Vegetation may range from **submerged and floating plants to emergent plants** along the margins.
- **Riverine Wetlands**
  - Riverine wetlands are found along **rivers and streams,** characterised by flowing fresh water. They can occur along the riverbanks or floodplains and are subject to periodic flooding based on seasonal water flow variations.
  - **Features:** These wetlands support vegetation and species that are adapted to the dynamic conditions of fluctuating water levels. They play crucial roles in flood control, water purification, and providing habitat for aquatic and terrestrial species.

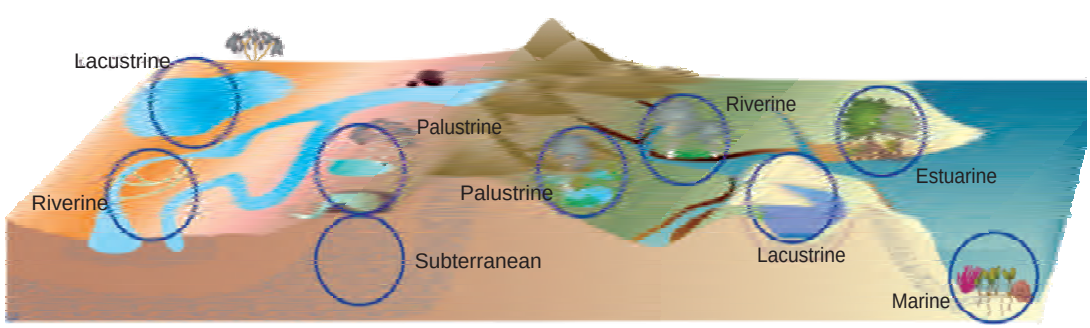


Fig. 4.3: Classification of Wetlands on the Basis of Distinct Features

❑ **Palustrine Wetlands**

- Palustrine wetlands are **non-tidal, freshwater wetlands** that include marshes, swamps, bogs, and fens. They are not associated with large bodies of water like lakes or oceans but may be connected to smaller water bodies such as ponds.
- **Features:** These wetlands are characterised by their diverse vegetation, ranging from **herbaceous plants in marshes to woody plants** in swamps. They are crucial for **groundwater recharge, carbon sequestration,** and providing habitat for numerous species.

❑ **Estuarine Wetlands**

- Estuarine wetlands are located at the **interface of rivers and the sea,** where freshwater mixes with saltwater. These transitional areas include salt marshes, mangrove forests, and tidal flats.
- **Features:** Estuarine wetlands are **highly productive ecosystems** that provide critical nursery habitats for fish and shellfish, protect coastlines from erosion, and filter pollutants from coastal waters.

Specific Wetland Types

❑ **Human-made Wetlands**

- **Definition:** These are wetlands constructed for **specific purposes,** such as water storage, aquaculture, or recreation. Examples include reservoirs, fish ponds, salt pans, and dams.
- **Examples: The East Kolkata Wetlands, a Ramsar site,** is an example of human-made wetlands used for wastewater treatment and aquaculture, showcasing sustainable resource management.

❑ **Lakes and Ponds**

- **Lakes and ponds, or lentic systems,** are inland freshwater habitats that vary widely in size and depth, providing critical resources for both aquatic and terrestrial organisms.
- **Examples: Wular Lake in Jammu and Kashmir** is one of the largest freshwater lakes in India that plays a crucial role in biodiversity conservation and supporting local livelihoods.

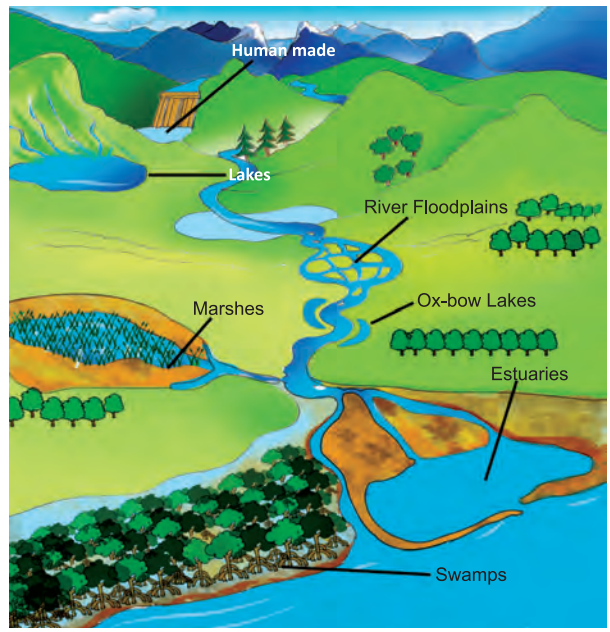


Fig. 4.4: Specific Wetland Types

❑ **River Floodplains**

- Floodplains are areas **adjacent to rivers or streams** that experience periodic flooding, enriching the soil and supporting diverse ecosystems.
- **Examples: The Yamuna floodplains are vital for Delhi's water supply,** demonstrating the importance of floodplains in urban water management.

❑ **Ox-bow Lakes**

- Oxbow lakes are crescent-shaped water bodies formed when a river meander is cut off, often due to silt deposition or changes in the river's course.
- **Examples: Ansupa Lake in Odisha** is an oxbow lake providing habitat for numerous species and supporting local fisheries.

These diverse wetland types and patterns underscore the ecological complexity and importance of wetlands in India. Conservation efforts must address the unique challenges and threats facing each type to ensure their preservation and the continuation of their vital ecological functions.

Distinction Between Lake and Wetland

The contrast between lakes and wetlands is critical for understanding their unique roles and properties in ecosystems. Here's a more detailed explanation of each point on the table:

Feature	Lake	Wetland
Origin	Lakes are formed through natural processes such as glacial activity, volcanic eruptions, tectonic movements, and river damming. Man-made lakes, or reservoirs, are created by damming rivers for various purposes.	Wetlands originate from flooding, sediment accumulation, sea-level rise, beaver dams, or human activities that create or expand waterlogged areas.
Water Depth	Lakes are characterised by deeper water bodies with well-defined open water areas. They vary in size and depth, often having areas deep enough to limit the growth of rooted plants to the edges.	Wetlands are defined by shallow waters, allowing sunlight to penetrate to the bottom and supporting a wide range of plant life. The water level can fluctuate seasonally, contributing to a dynamic ecosystem.

Vegetation	Vegetation in lakes is typically limited to the shoreline or littoral zone, where light can reach the bottom to support plant growth. Floating plants or algae may be present in deeper parts.	Wetlands boast a diverse array of vegetation covering the entire area, including grasses, reeds, mosses, and trees, depending on the wetland type. This supports a wide range of plant species, making wetlands highly productive.
Soil Type	The soil around and beneath lakes is less likely to be saturated year-round. It may dry out when the water recedes, supporting aquatic vegetation along the edges with mineral-rich soil.	Soil in wetlands is typically saturated or flooded for significant periods, creating anaerobic conditions that slow plant decomposition. This supports a distinct community of plants and microorganisms.
Ecosystem Role	Lakes serve as habitats for aquatic species, including fish, amphibians, and invertebrates. They are important freshwater reservoirs and play a critical role in the hydrological cycle.	Wetlands support specialised plants, animals, and microbes adapted to water-saturated conditions. They provide critical habitat and play key roles in water purification, flood control, and carbon sequestration.

Both lakes and wetlands play crucial roles in supporting ecological diversity and safeguarding aquatic ecosystems. **Lakes** serve essential functions such as recharging groundwater and preserving freshwater reservoirs. In contrast, **wetlands** offer benefits like erosion prevention, the provision of wildlife habitats, and the enhancement of water quality.

IGNITE YOUR MIND

Beyond the Surface: Lakes and wetlands may appear similar, but beneath the surface lies a distinct story. Unravel the key characteristics that differentiate these ecosystems and understand why this distinction is crucial for their conservation.

GLOBAL STATUS OF WETLANDS

- Global wetlands cover a vast and diverse range of ecosystems, including marshes, peatlands, mangroves, rivers, lakes and deltas.
- **Area and Distribution:** Wetlands cover approximately **6% to 9%** of the Earth's surface, translating to around **5.5 to 8 million square kilometers.** This area is distributed across every continent, reflecting the ecological diversity and geographical spread of wetlands.
- Currently, there are over **2,400** Ramsar Sites around the world. They cover over 2.5 million square kilometres, an area larger than Mexico.
- **Numbers and Types:** There are **millions of wetland sites worldwide,** ranging from the vast **Siberian peatlands, which are among the largest continuous wetland areas, to the extensive Pantanal,** the world's largest tropical wetland area located in South America. The exact number of wetland sites varies due to the dynamic nature of these ecosystems and differences in classification and mapping methodologies.

INDIAN STATUS OF WETLANDS

- India has achieved a significant milestone in wetland conservation, now hosting **80 Ramsar sites, up from earlier 75,** the highest number in South Asia.
- There are a total of approximately **27,403 wetlands** in India, with approximately **23,444 inland wetlands** and approximately **3,959 coastal wetlands.**

Ramsar Convention

- The **Ramsar Convention on Wetlands** stands as a landmark international agreement, established to address the growing concern over the rapid degradation and disappearance of wetland habitats around the globe.
- **Historical Context**
  - The genesis of the Ramsar Convention was driven by the recognition that wetlands are among the **most productive ecosystems on Earth,** yet they are being lost at an alarming rate due to anthropogenic causes.
  - Prior to the Convention, there was no global treaty specifically focused on the conservation of wetlands.
  - The agreement in Ramsar marked the first time nations came together to commit to the protection of a particular ecosystem type, setting a precedent for future environmental treaties.
- **Objectives and Goals**
  - The primary goal of the Ramsar Convention is to promote the conservation and **wise use of wetlands** through a wide range of actions at the national, regional, and international levels.
  - **"Wise use"** is defined by the Convention as the maintenance of wetlands' ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development.

- The objectives of the Convention are realized through **three main pillars:**
  - **Listing of Wetlands of International Importance:** Countries that join the Convention are required to designate suitable wetlands for inclusion in the List of Wetlands of International Importance (the Ramsar List) and ensure their effective management.
  - **National Wetland Policies:** Contracting Parties commit to developing and implementing national wetland policies or other effective measures to promote the conservation and wise use of wetlands within their territories.
  - **International Cooperation:** The Convention promotes international cooperation on wetland issues, including the sharing of knowledge and collaborative projects, particularly in the management of trans-boundary wetlands and shared water systems.

- **Global Impact**
  - Since its inception, the Ramsar Convention has grown to include over 2,400 Ramsar Sites on the territories of 172 Convention Contracting Parties across the world, covering more than 2.5 million square kilometres.
  - This expansive network of protected areas highlights the Convention's significant role in global efforts to preserve the world's wetlands.
  - The Ramsar sites, as these designated areas are known, represent the ecological diversity of wetlands, including marshes, peatlands, floodplains, rivers, lakes and coastal zones, among others.

Montreux Record

- **The Montreux Record** is a register of wetland sites on the **Ramsar List of Wetlands of International Importance** where changes in ecological character have occurred, are occurring, or are likely to occur due to technological developments, pollution, or other human interference.
- Established in **1990 at the Ramsar Convention's Conference of the Parties in Montreux, Switzerland,** the Montreux Record is part of the Ramsar Convention's mechanism to bring attention to and address specific challenges facing designated wetlands.
- **Current Montreux Record Sites in India:** India has two sites listed on the Montreux Record:
  - **Keoladeo National Park, Rajasthan:** Initially designated a Ramsar site for its importance as a bird sanctuary, Keoladeo National Park was added to the Montreux Record due to **concerns over water management** and invasive species, which have impacted its ecological character.
  - **Loktak Lake, Manipur:** This site was included in the Montreux Record due to **issues related to water regulation from a hydroelectric project, agricultural run-off, and encroachment,** which have led to significant ecological changes.
- **Note: Chilka Lake,** Odisha was placed in the record but was later removed from it.

INDIA AND THE RAMSAR CONVENTION

- **India's commitment:** Signed the Ramsar Convention on February 1, 1982, demonstrating its dedication to wetland conservation.
- **Largest Wetland:** Sundarbans claims the title of India's largest Ramsar Site, showcasing its diverse ecosystem.
- **Pioneers in Conservation:** Chilika Lake and Keoladeo National Park were the first Indian sites recognized as Ramsar Sites, highlighting early efforts.
- **Smallest Wetland:** Renuka Wetland in Himachal Pradesh, spanning just 20 hectares, holds the distinction of being India's smallest.
- **Regulation and Protection: The Wetlands (Conservation and Management) Rules, 2017,** ensure the legal framework for wetland protection.
- **Growing Network:** As of February 2024, India boasts 80 Ramsar Sites, signifying its expanding conservation efforts.
- **State Leaders:** Tamil Nadu leads with the most Ramsar Sites (16), followed by Uttar Pradesh (10), showing their commitment to wetland preservation.
- **Recent 5 new sites** were added in the list of Ramsar sites in india:
  - Karaivetti Bird Sanctuary (Tamil Nadu), Longwood Shola Reserve Forest (Tamil Nadu), Magadi Kere Conservation Reserve (Karnataka), Ankasamudra Bird Conservation Reserve (Karnataka), Aghanashini Estuary (Karnataka)

Few Important Wetlands

Wetland Lake	Location	Approximate Size
Vembanad-Kol Wetland	Kerala	1,780 sq km
Chilika Lake	Odisha	1165 to 900 sq.km
Loktak Lake	Manipur	287 sq km
Wular Lake	Jammu & Kashmir	189 sq km
Sambhar Lake	Rajasthan	190-230 sq km
Hokera Wetland	Jammu & Kashmir	14 sq km
Rudrasagar Lake	Tripura	2.5 sq km
Sasthamkotta	Kerala	3.73 sq km

Criteria for Identification

The identification and designation of wetlands in India are based on specific criteria, aligning with both national priorities and international guidelines:

- **Criterion 1:** A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
- **Criterion 2:** A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
- **Criterion 3:** A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
- **Criterion 4:** A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
- **Criterion 5:** A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
- **Criterion 6:** A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
- **Criterion 7:** A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/ or values and thereby contributes to global biological diversity.
- **Criterion 8:** A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
- **Criterion 9:** A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

IMPORTANCE OF WETLANDS

Wetlands are among the most valuable ecosystems on the globe, that provide a diverse range of services to both the **environment and human societies.** Their importance extends across multiple aspects, including **biodiversity protection, climate change mitigation, water purification, flood control, and recreational and cultural value.** Here's a detailed look at each of these aspects:

- **Biodiversity Hotspot**
  - They provide a unique habitat that supports an extensive variety of life forms, many of which are specially adapted to the wetland environment. Wetlands serve as a **cradle** for biodiversity.
  - Although they cover only around **6 percent of the Earth's land surface, 40 percent of all plant and animal species live or breed in wetlands.** Best examples of these are **One Horned Rhino in Assam marshes, Jaguars the large cats found in the wetland areas of South and Central America.**
  - This includes a wide range of plant species, from **floating water lilies to towering cypress trees,** as well as a diverse array of animal life, including amphibians, reptiles, birds, fish, and invertebrates.
- **Habitats of migratory birds**
  - Wetlands also serve as crucial stopover points for migratory birds, offering resting and feeding grounds that are vital for their survival during long migrations.
  - These ecosystems provide a diverse array of avian species with food, shelter and nesting sites, playing a pivotal role in the survival of many migratory bird populations.
  - **Examples:**
    - **Keoladeo National Park (Bharatpur Bird Sanctuary), Rajasthan:** A renowned Ramsar site, this park is a vital wintering area for large numbers of aquatic birds from **Afghanistan, Turkmenistan, China, and Siberia.** It hosts thousands of birds, including the **rare Siberian crane.**
    - **Chilika Lake, Odisha: Asia's largest brackish water lagoon** is a hotspot for migratory birds, with **over one million birds visiting each winter.** Species such as **flamingos, white-bellied sea eagles, and ospreys are common sights.**
- **Water Purification**
  - As water flows through a wetland, the combination of plant roots, soil, and associated microbial communities **filters out pollutants,** including sediments, **heavy metals,** excess nutrients, and harmful pathogens. They are natural water purifiers.

- This natural filtration process **improves water quality** by breaking down pollutants into less harmful substances or trapping them in the sediment, thus preventing them from reaching larger water bodies like rivers, lakes, and oceans.
- This service is invaluable in maintaining clean water supplies for wildlife and human populations alike.

❑ **Flood Protection**

- Wetlands play a crucial role in **flood mitigation.** Their ability to **absorb and store excess rainfall and surface water runoff** makes them natural flood buffers, reducing the impact and severity of floods downstream.
- During heavy rainfalls or snowmelts, wetlands act like sponges, soaking up excess water.
- Then, they release this water slowly over time, mitigating the potential for flood damage in nearby communities.
- This capacity not only protects **human settlements and agricultural lands** from flooding but also reduces the economic costs associated with flood damage.

❑ **Economic Importance**

- **Fisheries:** Wetlands serve as **breeding and nursery grounds** for many fish species, supporting commercial and subsistence fisheries that are vital for the livelihoods of millions of people worldwide.
- **Timber and Plant Products:** Wetlands provide resources such as **timber, peat, and medicinal plants,** contributing to various industries and traditional uses.

❑ **Climate Change Mitigation**

- Wetlands play an important role in combating climate change by acting as powerful natural allies in a variety of ways, including **carbon sequestration, climate control, and resilience to extreme weather events.** Their role in this global crisis cannot be emphasised.
- Wetlands play an important role as **carbon sinks.** Wetlands absorb carbon dioxide from the atmosphere and store it in **plant biomass** and soil through a process known as **carbon sequestration.**
- This potential is especially evident in peatlands and mangrove forests, which store massive amounts of carbon, lowering greenhouse gases that contribute to global warming.
- Furthermore, wetlands aid in climate regulation by **moderating local climates.**
- **Evapotranspiration** from wetland surfaces can lower local temperatures, **reducing the effects of heatwaves.**
- This natural air-conditioning effect is especially important in metropolitan settings, where wetlands can help reduce the urban heat island effect.
- They **lessen flood risk by absorbing excess rainwater.** Coastal wetlands, such as mangroves and salt marshes, serve as natural barriers to storm surges and sea-level rise, shielding inland settlements from erosion and damage.

❑ **Recreational and Cultural Values**

- Beyond their **ecological functions,** wetlands offer numerous recreational and cultural benefits.
- They are places of beauty and tranquility, offering opportunities for activities such as bird watching, hiking, fishing, and photography.
- Wetlands are also culturally significant to many communities around the world, providing a source of inspiration for art, folklore, and spiritual practices.
- They contribute to the well-being of people by offering spaces for relaxation, education, and connection with nature.

Case Study: Wetlands in Karnataka - A Valuable Asset

Overview: Dr. T V Ramachandra, a faculty member at the **Centre for Ecological Sciences, Indian Institute of Science (IISc),** highlighted the **significant economic and ecological value of wetlands in Karnataka.**

Importance of Wetlands

❑ **Economic Value:** The total wetland area in Karnataka is approximately **2,81,299.5 hectares.** These wetlands provide benefits with an economic value of **Rs 284.52 billion annually.**

❑ **Services Provided:** Wetland services are categorized into provisioning (e.g., fishing, fodder), regulating (e.g., groundwater recharge, bioremediation), and cultural (e.g., recreation) services.

❑ **Catchment Area Integrity:** Dr. Ramachandra emphasized the importance of maintaining the **integrity of lake catchment areas** for the protection of wetlands.

❑ **Impact of Human Activities:** The construction of the **Linganamakki dam on the Sharavathi river,** for example, significantly **altered the region's rainfall patterns,** affecting the local ecosystem.

Challenges and Recommendations

❑ Dr. Ramachandra pointed out that **75% of lakes have been lost in recent decades** due to encroachment and mismanagement. He stressed the need for government action to protect the integrity of catchment areas.

❑ The case of **Nagashetty Halli,** where groundwater levels plummeted following the disappearance of the lake, illustrates the critical role of wetlands in groundwater recharge and the dire consequences of wetland loss.

Conclusion: Wetlands in Karnataka are invaluable assets that provide significant economic benefits and ecosystem services. Protecting these areas requires concerted efforts to maintain catchment integrity, restore interconnectivity between water bodies, and engage in sustainable management practices.

STATUS OF WETLAND DEPLETION

Wetlands, which are regarded as some of the world's most commercially valuable and environmentally significant habitats, are disappearing at an alarming rate, three times faster than forests. This stark revelation is based on the **Ramsar Convention's first-ever worldwide Wetland Outlook,** a worldwide **treaty approved by 170 countries** dedicated to the protection and responsible use of wetlands.

Main Findings

- **Accelerated Loss:** Approximately **35% of the world's wetlands were lost between 1970 and 2015,** with the rate of loss **accelerating annually since 2000.** This rapid depletion underscores the urgent need for comprehensive conservation strategies to safeguard these critical ecosystems.
- However, **more than 25%** of all wetland plants and animals are at risk of extinction due to habitat loss and degradation.

Indian Status of Wetland Depletion

- India has witnessed a significant loss of its wetland ecosystems over the **last three decades,** sounding the alarm among conservationists and environmental experts.
- According to estimates by **Wetlands International,** a global not-for-profit organization based in the Netherlands, **nearly two out of every five wetlands in India have disappeared in the last 30 years.**
- This loss is not just in terms of area but also in the quality of water bodies, with **40%** experiencing a decline in conditions suitable for aquatic life.

Main Findings

- **Rapid Urbanization:** Prominent examples of wetland depletion include **Najafgarh Lake near Delhi and Pallikaranai in Chennai,** both of which have **shrunk by over 50%** due to infrastructural development, expansion of housing plans, and unsustainable water exploitation.
- **Wetland Coverage:** India currently hosts around **2.2 lakh large wetlands covering areas over 2.2 hectares and an additional 5.5 lakh smaller ones.** Despite this, only about **60,000 large wetlands** within protected forest areas are considered relatively safe from degradation.
- **The Development Crisis:** The loss and degradation of wetlands are not just environmental issues but also development crises. The **2015 Chennai floods** serve as a stark reminder, where unplanned development led to the degeneration of the city's wetlands, compromising its resilience to floods and resulting in substantial economic losses.

REASONS FOR WETLAND DEPLETION

There are many different causes of wetland depletion, all of which contribute to the collapse of these important ecosystems. The causes of wetland depletion are connected with the larger issue of natural resource depletion, which includes a variety of activities and behaviours. Given below are the elements that contribute to wetland depletion:

- **Overpopulation**
  - The **demand for natural resources,** including those provided by wetlands; is continuously on the rise as a result of the expanding global population.
  - As the population expands, so does the need for land for housing, agriculture, and industrial development, often at the **expense of wetland areas.**
- **Poor Farming Practices**
  - Agriculture, especially when **practiced unsustainably,** can lead to the degradation of wetlands.
  - **Poor irrigation practices** contribute to the salinization and alkalization of soils, while **excessive use of pesticides and fertilisers** can pollute wetland waters.
  - Additionally, the conversion of wetlands into farmland reduces their extent and ecological function.
- **Logging and Deforestation**
  - The removal of forests for timber, agriculture, and urban development not only destroys terrestrial habitats but also affects adjacent wetlands.
  - **Between 1990 and 2016,** the **World Bank reported a net loss of 1.3 million square kilometres** of world forest.
  - The gross loss per year thereafter was over **13 million hectares,** and by **July 2022,** the net loss of world forest was around **17 million hectares.**
  - Deforestation can alter the hydrological cycles that support wetlands, leading to their drying up or becoming less diverse biologically.
- **Overconsumption of Natural Resources**
  - Large-scale mineral and oil exploration **began in the 1760s** industrial revolution, and the practice has continued to develop, resulting in increasing natural oil and mineral depletions.
  - The demand for water, minerals, and other natural resources leads to the exploitation of wetlands.
  - Activities such as mining and the extraction of peat from wetlands directly remove the materials that constitute the wetland ecosystem, leading to its degradation or complete loss.

❑ **Pollution**

- Wetlands are **particularly vulnerable to pollution from agricultural runoff, industrial discharges, and urban wastewater.**
- Pollutants can alter the water chemistry of wetlands, harm aquatic life, and reduce the water quality, undermining the wetlands' ability to support diverse life forms and purify water.

❑ **Industrial and Technological Development**

- The expansion of industrial activities and infrastructure development **often encroaches on wetlands (mainly in metro cities like Chennai, Mumbai, Bengaluru, etc.)**
- The construction of roads, buildings, and other structures can lead to the direct loss of wetland areas or alter their hydrology, making it difficult for these ecosystems to sustain their functions.

MITIGATION MEASURES

Addressing wetland depletion requires a multimodal approach that includes conservation, restoration, and sustainable management methods. Here are a few essential mitigation measures:

❑ **Controlling Deforestation**

- Implementing programmes to reduce deforestation and promote reforestation can help protect wetland ecosystems.
- Initiatives like **REDD (Reducing Emissions from Deforestation and Forest Degradation)** aim to conserve forested areas, which are often integral to the health of wetlands.

❑ **Reducing Resource Consumption**

- Encouraging the **reduction of oil, mineral and material consumption** can lessen the pressure on wetlands.
- This includes promoting **sustainable agriculture,** reducing reliance on fossil fuels, and encouraging the use of alternative materials.

❑ **Exploring Renewable Energy**

- The adoption of renewable energy sources, such as **solar and wind power,** reduces the need for fossil fuel extraction and can help mitigate climate change, benefiting wetlands indirectly by preserving their water regimes and reducing extreme weather events.

❑ **Protecting Wetlands and Coastal Ecosystems**

- Direct protection of wetlands through **legislation, conservation programmes, and the establishment of protected areas** is crucial.
- Efforts should focus on maintaining or restoring the **natural hydrology of wetlands** and protecting their boundaries from encroachment.

❑ **Sensitization and Awareness Creation**

- Educating the public about the importance of wetlands and the **consequences of their depletion** can foster a culture of conservation.
- Awareness campaigns can encourage community involvement in wetland conservation and promote behaviours that reduce the impact on these ecosystems.

Implementing these measures requires coordinated efforts from governments, non-governmental organisations, communities and individuals. By addressing the root causes of wetland depletion and promoting sustainable practices, it is possible to conserve these vital ecosystems for future generations.

IGNITE YOUR MIND

Vanishing Treasures: Despite their immense value, wetlands are disappearing at an alarming rate. What are the primary culprits behind this depletion, and what potential consequences does it hold for both the environment and human well-being? Explore innovative approaches and restoration strategies employed to bring these vital ecosystems back to life around the world.

GLOBAL CONSERVATION EFFORTS FOR THE WETLANDS

Recent activities and initiatives aimed at preserving these crucial habitats show that the global movement to protect wetlands has **gained tremendous traction.** However, governments and international organisations have increased their efforts to protect these natural areas, recognising their importance in biodiversity conservation and climate change mitigation. The following is an in-depth look at the global measures used to safeguard wetlands:

❑ **Ramsar Convention on Wetlands**

- The **Ramsar Convention, commonly known as the Convention on Wetlands,** is an international convention that promotes the conservation and sustainable use of wetlands.
- The convention was signed in **1971 in the Iranian city of Ramsar and went into effect in 1975.**
- A pivotal moment in the drive to protect wetlands came during the **November 2022** meeting of the Ramsar Convention on Wetlands.

❑ **World Wetland Day**

- **World Wetlands Day** is observed annually on **February 2.** It aims to raise global awareness of the critical importance of wetlands for people and the environment.

- This day also marks the adoption of the **Convention on Wetlands on February 2, 1971, in Ramsar, Iran.**
- The topic for **World Wetlands Day 2024 is 'Wetlands and Human Wellbeing,'** emphasising the vital role of wetlands in nature and society.

❑ **United Nations Biodiversity Conference Agreement**
- At the recent **United Nations Biodiversity Conference,** countries reached a landmark agreement to protect nature.
- This deal included a specific **provision to restore at least 30% of degraded inland water bodies** and conserve healthy freshwater ecosystems equitably.
- This agreement underscores the global commitment to wetland conservation as part of broader biodiversity and environmental protection efforts.

❑ **UN Decade on Ecosystem Restoration**
- In line with the **UN Decade on Ecosystem Restoration,** there is a call to stop policies and subsidies that incentivize deforestation and wetlands degradation.
- The focus is on promoting the urgent restoration of these ecosystems and guiding investments to protect priority ecosystems, such as peatlands.
- Encouraging the private sector to commit to deforestation and peatland-drainage-free supply chains has also been emphasised upon.

❑ **Global Conservation Initiatives**
- Countries worldwide are beginning to restore their wetlands, with notable initiatives including the **development of sponge cities in China** and the government-backed restoration of the **United Kingdom's Great North Bog.**
- These efforts are crucial for carbon and water storage, showcasing the practical steps being taken to bring wetlands back from the brink of degradation.

❑ **Financial and Political Will**
- The **United Nations Environment Programme (UNEP)** highlights that adequate finance and political will are key to conserving and restoring wetlands.
- The **UNEP's 2022 State of Finance for Nature report** calls for investments in **nature-based solutions** to ramp up to **$384 billion per year by 2025** to meet climate, biodiversity, and land degradation goals.

❑ **International Solidarity and Funding**
- The need for **increased international solidarity,** capacity-building, and funding echos the urgency of protecting wetlands.
- The global community is nudged upon to ramp up efforts to protect the services provided by wetlands, upon which societies depend for a sustainable future.

These global measures reflect a growing recognition of the value of wetlands to economies, cultures, and the environment. The momentum to protect and restore wetlands is a critical step towards countering the climate crisis and preserving biodiversity for future generations.

MEASURES TAKEN BY INDIA TO PROTECT WETLANDS

India has been actively involved in wetland conservation through a variety of laws, programmes, and projects, recognising the essential role that wetlands play in biodiversity, flood control, groundwater recharge, and giving livelihoods to millions of people. Here are some important conservation efforts by India for wetlands:

Ramsar Convention on Wetlands

❑ **India is a signatory to the Ramsar Convention,** an international treaty for the conservation and sustainable use of wetlands.

❑ India has designated several wetlands of international importance under this convention, committing to their conservation and sustainable use.

National Wetland Conservation Programme (NWCP)

❑ The **National Wetland Conservation Programme (NWCP)** was merged with the **National Lake Conservation Plan (NLCP)** into the **'National Plan for Conservation of Aquatic Eco-systems'** (NPCA) in February 2013 by the **Ministry of Environment, Forest & Climate Change (MoEF&CC).**

❑ This merger aims to enhance synergy and avoid overlap between the two schemes, focusing on the **conservation and management of wetlands** and lakes across India.

❑ The NPCA is implemented on a cost-sharing basis between the central government and respective state governments, emphasising a collaborative approach to wetland conservation.

❑ Under the NPCA, **financial assistance is provided to states and union territories** for the conservation and management of identified wetlands and lakes. This initiative reflects the government's commitment to preserving the ecological character of wetlands while promoting their wise use for sustainable development.

❑ Additionally, the **Wetlands (Conservation and Management) Rules, 2017,** were notified under the Environment (Protection) Act, 1986, establishing a regulatory framework for wetland conservation across India.

❑ These rules empower state and UT wetland authorities to identify and notify wetlands, aiming to conserve, manage, and maintain their ecological character.

Wetlands (Conservation and Management) Rules, 2017

❑ The **Wetland Conservation and Management Rules, 2017,** outline specific provisions for the protection and wise use of wetlands in India.

- Establishment of State Wetland Authorities (SWAs) in each state and union territory, headed by the state's environment minister.
- Inclusion of government representatives and specialists in hydrology, socio-economics landscape design, fisheries, and wetland ecology within SWAs.
- Adoption of the "smart use principle" for wetland management, with sustainable practices termed as "wise use."
- Decentralization of power to SWAs, enabling them to compile lists of regulated activities and prohibited actions within notified wetlands and their influence zones.
- Tasks assigned to SWAs include recommending strategies for more effective wetland utilization and raising awareness among local communities and stakeholders.
- Replacement of the Central Wetlands Regulatory Authority with the National Wetland Committee (NWC), led by the secretary of the Ministry of Environment, Forest and Climate Change (MoEFCC).
- Prohibition of activities such as encroachment, industrial establishment, waste disposal, and discharge of untreated effluents through regulations.
- Mandate for state authorities to compile lists of all wetlands and those requiring notification within six months.
- Establishment of a foundation for a comprehensive digital inventory of wetlands to be updated every decade.

Integrated Wetland Management Programme

- This programme involves various stakeholders, including **government agencies, NGOs, and local communities,** in the conservation of wetlands.
- It focuses on an integrated approach to managing wetlands that includes **biodiversity conservation, pollution control, and sustainable** use practices.

Wetland Conservation and Management Initiatives by State Governments

- Several state governments in India have launched their own initiatives to protect and conserve wetlands within their jurisdictions.
- These include the **establishment of wetland authorities, the implementation of state-specific wetland conservation programmes,** and the declaration of wetland conservation reserves.

Community Participation and Awareness Programmes

- Recognising the importance of local communities in wetland conservation, the government and various NGOs conduct **awareness and capacity-building programmes.**
- These initiatives aim to educate the public about the value of wetlands and engage them in conservation efforts.

Case Study: Conservation Success of Sarus Cranes in Kheda Wetland

In **Kheda, Gujarat,** a concerted conservation effort has led to a remarkable recovery of the Sarus Crane population. Over **seven years, from 2015 to 2022,** the population of the **world's tallest flying bird** in the wetlands of **Matar Taluka nearly doubled, increasing by 98% from around 500 to nearly 992 individuals.**

Strategies and Outcomes

- **Community Engagement:** The transformation began with the local villagers and conservationists rallying to protect the Sarus Cranes from the brink of extinction. Farmers from about **35 villages** near the Pariej wetland learned to coexist with the cranes, allowing their fields to remain undisturbed during the breeding season between June and September.
- **Conservation Awareness:** Initially perceived as a nuisance due to their nesting habits in paddy fields, the **Sarus Cranes became a symbol of pride for the community.**
- **Strategic Partnership:** The **Kheda district forest department** collaborated with **United Phosphorus Limited (UPL)** to launch the **Sarus Conservation Project in 2015.** This initiative covered 36 project villages in Anand and Kheda districts, involving 88 voluntary **Rural Sarus Protection Groups (RSPGs)** who sensitized nearly 5,000 farmers in the wetland area.
- **Compensation and Support:** The forest department offered ex gratia for crop damage due to Sarus breeding, but the community's realization that the birds caused minimal damage led to a harmonious coexistence. No compensation claims have been made by the farmers, indicating their support for the cranes' presence.

Research and Monitoring

- Research and monitoring are crucial for the effective conservation of wetlands.
- India supports various research projects and monitoring initiatives to study **wetland ecosystems, assess their health, and identify threats**.
- This information is used to inform conservation strategies and actions.

Restoration Projects

- India undertakes wetland **restoration projects** to rehabilitate degraded wetlands (like the successful **Chilika Lake** project).
- These projects involve activities such as **reforestation,** control of invasive species, pollution cleanup and hydrology hydrology restoration to revive the ecological character of wetlands.

These efforts reflect India's commitment to conserving its wetlands, recognising their importance for biodiversity, climate regulation, water security, and the livelihoods of millions of people.

Restoration of Chilika Lake: A Case Study

Chilika Lake, Asia's largest brackish water lagoon located in **Odisha, India,** underwent a significant restoration that transformed it into a conservation success story. Facing ecological degradation due to siltation, invasive species, and disrupted water exchange with the **Bay of Bengal, the Chilika Development Authority (CDA),** in collaboration with various stakeholders, initiated comprehensive restoration efforts in the late 1990s.

Restoration Measures

- **Opening a New Mouth to the Sea:** This critical intervention in **2000** restored the lake's natural salinity levels, improving water quality and enhancing fish stocks.
- **Weed Management:** Control of invasive weeds like water hyacinth helped recover navigable waterways and habitats.
- **Community Engagement:** Involving local communities in sustainable fishing and eco-tourism promoted alternative livelihoods and reduced anthropogenic pressures on the lake.

Outcomes

- The restoration led to a resurgence in biodiversity, including an increase in fish catch and the return of migratory birds.
- Chilika Lake's economic value to local communities soared, thanks to improved fisheries and the growth of eco-tourism.
- In recognition of its recovery, **Chilika Lake was removed from the Ramsar Convention's Montreux Record in 2002,** highlighting the global significance of its restoration.

Way Forward

To maintain and preserve wetlands, which are important ecosystems that provide multiple benefits to the environment, wildlife and human societies. The following measures can be taken:

- **Support Wetland Conservation Efforts:** Engage with organisations and initiatives dedicated to the conservation and protection of wetlands. This can involve **donating, volunteering, and advocating for policies** that protect wetlands.
- **Educate Others: Increase awareness** about the critical role of wetlands in environmental balance. Share knowledge on the importance of wetlands and the threats they face to encourage more people to participate in conservation efforts.
- **Implement Sustainable Land-Use Practices:** Adopt **land-use practices that minimise human impact on wetlands.** This includes environmentally friendly farming methods **(zero effect, zero defect),** reducing pesticide and fertiliser use, and avoiding disturbance to wetlands.
- **Use Environmentally Friendly Development Methods:** Employ development methods that are considerate of wetland ecosystems. Techniques such as using permeable pavements, preserving existing vegetation, and avoiding construction in sensitive areas can help minimise environmental impact.
- **Create Wetland Reserves:** Designate areas as protected wetland reserves to conserve them for future generations. These reserves can serve as sites for **research, education, and recreation** while providing crucial habitats for wildlife.
- **Implement Effective Water Management Practices: Regulate water flow into and out** of wetlands to mitigate flood and drought risks and enhance the health of these ecosystems.
- **Reduce Pollution:** Limit the amount of **pollution reaching** wetlands by reducing chemical and plastic use, properly disposing of waste, and controlling pollutant discharge into these areas.
- **Minimise the Impact of Recreational Activities:** Regulate and educate on **recreational activities** like boating and fishing to ensure they do not harm wetland environments.
- **Support Restoration Efforts:** Participate in efforts to restore degraded or damaged wetlands to their natural state. Activities can include **planting native vegetation, removing pollutants, and applying effective water management.**
- **Monitor Wetlands:** Conduct regular monitoring of wetlands to assess their health and identify potential threats. This information is crucial for **targeted protection and restoration efforts.**

These measures emphasise the importance of collective action and responsibility in protecting wetlands. By implementing these strategies, we can ensure that wetlands continue to provide their invaluable benefits to the environment, wildlife, and human communities.

MANGROVE ECOSYSTEMS

Mangroves are unique ecosystems that exist at the **land-sea interface in tropical and subtropical places** around the world. These ecosystems are unique not just for their ability to thrive in difficult coastal conditions but also for their high ecological and economic significance.

Introduction to Mangroves

- Mangroves are a **type of littoral plant formation** found along **tropical and subtropical sheltered** coastlines. They are woody **plants** that form dense forests along sheltered coastlines within the tropics and subtropics.

Fig. 4.5: Mangroves

- They stand out for their incredible capacity to survive in **salty, oxygen-deficient soils** and for their resistance to frequent **tidal flooding.**
- Mangroves encompass a variety of tree and shrub species that share these unique adaptations, rather than being closely related genetically.
- There are **approximately 54 true mangrove species** across **16 different families,** but when including all plants that live in mangrove environments, the number **exceeds 80 species.**

Characteristics of Mangrove Vegetation

Mangroves are intriguing ecosystems with **distinct adaptations,** making them among the most productive and **physiologically complex places** on Earth. Their capacity to live in **intertidal zones,** where saltwater and freshwater meet, demonstrates their tremendous resilience and ecological significance. Let's go deeper into the qualities of mangrove plants that allow them to live and thrive in such harsh environments.

The following are some of the characteristics of mangroves:

Adaptations to Salinity

- Mangroves have developed specialised adaptations to cope with the **high salinity** of their coastal habitat.
- These adaptations are crucial for their survival in environments that would be inhospitable to most other plant species.
- **Salt Secretion:** Many mangrove species have **specialised salt glands on their leaves** that actively **secrete excess salt** absorbed from the water. This mechanism allows them to regulate their internal salt concentration, maintain water balance, and perform essential physiological processes. For example, the **black mangrove (Avicennia germinans)** exhibits this trait, with visible salt crystals often forming on the surface of its leaves.
- **Salt Exclusion:** Other mangroves prevent **salt from entering their tissues altogether.** They have a **selective filtration system** at the **root level** that blocks the entry of salt ions from the water. This adaptation is seen in the **red mangrove (Rhizophora mangle),** which can **exclude over 90%** of the salt in seawater.

Root Systems

- The root systems of mangroves are not only adapted for **stability in soft, oxygen-poor soils** but, they also play a critical role in oxygen exchange and habitat creation.
- **Pneumatophores:** Also known as **air roots,** pneumatophores are those that rise above the soil and water, facilitating gas exchange in **oxygen-deficient environments.** These roots are equipped with **lenticels, small pores** through which oxygen enters. The **grey mangrove (Avicennia marina),** for instance, features prominent pneumatophores that help it breathe in submerged conditions.
- **Stilt roots:** Stilt roots are a distinctive feature of certain mangrove species, most notably the red mangrove (Rhizophora spp.). These specialized aerial roots **extend from the trunk or branches and arch downward into the soil or water,** providing critical support and stability to the mangrove trees in the soft, unstable sediments of coastal and estuarine environments.
- **Prop Roots:** Some mangroves, like the **red mangrove,** develop sturdy aerial roots that arch down into the water from the **trunk and branches.** These prop roots provide stability and support in the soft mud, while their porous structure allows for oxygen uptake. They also create a complex underwater habitat for marine organisms.

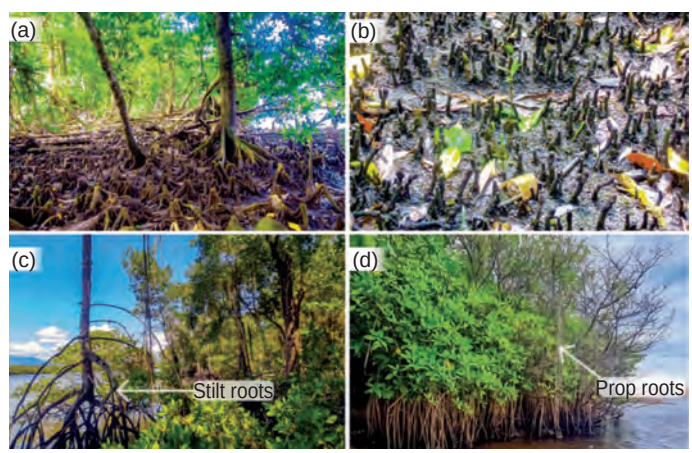


Fig. 4.6: Mangrove Root System (a) Knee Roots, Bruguiera spp., (b) Pneumatophores, Avicennia Marina. (c) Stilt Roots, Rhizophora spp and (d) Prop Roots, Rhizophora spp

Reproductive Strategies

- Mangroves have unique reproductive adaptations that ensure the **successful dispersal** and establishment of their offspring in the dynamic coastal environment.
- **Viviparous:** Unlike most plants, mangroves exhibit **vivipary, where seeds germinate while still attached to the parent tree.** These germinated seeds, known as **propagules,** can float and survive in water for extended periods before settling in the mud to grow. This strategy allows mangroves to disperse their offspring over large distances. The **propagules of the red mangrove** are a classic example, capable of floating and rooting far from their parent tree.

These traits highlight the adaptability and ecological value of mangroves. They not only survive in harsh conditions, but they also maintain a diverse ecosystem and provide critical services such as coastal protection, carbon sequestration, and support for fisheries. Protecting mangrove forests is critical to the health of coastal habitats and the communities that rely on them.

GLOBAL DISTRIBUTION OF MANGROVES

- Mangroves are tropical and sub-tropical coastal ecosystems found across the globe, primarily **between latitudes 25° N and 25° S.**
- These unique ecosystems cover approximately **137,000 square kilometers (about 53,000 square miles) worldwide,** according to the **World Atlas of Mangroves.**
- The distribution of mangroves is not uniform, with the largest extents found in Asia, Africa, Oceania, and the Americas.
- **Global Distribution:**
  - Asia hosts the largest area of mangroves, with countries like **Indonesia, Bangladesh, and India** having significant mangrove forests.
    - **Indonesia** alone accounts for approximately **20%** of the world's mangroves, making it the country with the largest mangrove area.
    - The **Sundarbans,** shared between Bangladesh and India, is the largest single block of tidal halophytic mangrove forest in the world.
  - Africa has extensive mangrove forests along the east coast, including **Madagascar,** and in the west along the coasts of **Nigeria and Cameroon.**
  - Oceania's mangrove ecosystems are prominently found in **Australia,** particularly in the northern regions, and **Papua New Guinea.**
  - The Americas have substantial mangrove forests, with **Brazil, Mexico, and the United States** (Florida) hosting significant areas.

Why are Mangroves Only Found in Tropical Regions?

- **Warm Temperatures:** Mangroves thrive in the warm temperatures of tropical regions. They are **sensitive to cold,** and most species cannot survive in temperatures that drop below freezing. The consistent warmth of the tropics supports their growth year-round.
- **High Humidity and Rainfall:** Tropical regions typically have **high humidity and significant rainfall,** creating ideal conditions for mangroves. These conditions support the freshwater needs of mangroves and help them manage the salt from their saline environment.
- **Intertidal Zones:** Mangroves are adapted to grow in **intertidal zones,** where the **land meets the sea.** These areas are abundant in tropical regions and provide the unique mix of freshwater and saltwater, along with soft, sediment-rich soils, that mangroves need to anchor their complex root systems.

MANGROVES IN INDIA

The current **biennial State of Forest Report (2021)** highlights India's efforts in mangrove conservation, which have yielded good outcomes. The country has seen an overall increase in mangrove cover, which is a noteworthy accomplishment given the global threats to these essential ecosystems.

Mangrove Cover in India

- **Total Mangrove Cover:** India's mangrove cover now spans **4992 square kilometers** (approximately 1.2 million acres), accounting for **0.15% of the country's total geographical area.** This represents an increase of **54 square kilometres (1.10%)** compared to the previous assessment.
- **Regional Distribution: According to ISFR** (Indian State of Forest Report), 2021 -The distribution of mangroves in India is concentrated in specific regions, with **West Bengal holding the largest share at 42.45%** of the country's total mangrove cover. **Gujarat** comes in **second with 23.66%,** and the **Andaman and Nicobar Islands are third with 12.39% and Andhra Pradesh with 8.12% and Maharashtra comes fifth with 6.44%.**
  - Notably, Gujarat has shown the maximum increase in mangrove cover, with an addition of 37 square kilometres (over 9,000 acres).
- **Significant Areas:** The **South 24 Parganas district in West Bengal alone accounts for 41.85% of the country's mangrove cover.** This district is home to the Sundarbans National Park, which harbours one of the largest mangrove forests globally and is a **UNESCO World Heritage Site.**

Fig. 4.7: Mangrove Ecosystem of India

Importance of Mangroves

Mangrove forests, with their exceptional resilience and ecological value, serve critical roles in coastal protection, biodiversity conservation, and human livelihoods. The following is a detailed explanation of the various values of mangroves:

Coastal Protection and Cyclone Mitigation

- Mangroves are frontline defenders against **coastal erosion, storm surges, and tsunamis.**
- Their complex root systems not only stabilise shorelines but also act as natural barriers that dissipate the energy of incoming waves and tides, significantly reducing the impact of strong cyclones.
- Studies have shown that **mangroves can reduce wave height by between 13 and 66% over 100 m,** effectively protecting shorelines from damaging winds and waves.
- For instance, during the **2004 Indian Ocean tsunami,** regions shielded by mangroves saw markedly less destruction.
- When **super cyclone Amphan** wreaked havoc on the Sundarbans coast in May 2020, the mangroves played a critical part in **safeguarding millions of people's lives** and livelihoods by acting as a bio-shield and protecting the embankments.

Biodiversity Hotspots

- Mangroves are biodiversity hotspots, **providing essential habitat, breeding grounds, and nurseries** for a diverse array of species.
- The **Sundarbans,** the **world's largest mangrove forest,** is a prime example, offering habitat to the **Royal Bengal Tiger** and countless other species.
- This biodiversity is crucial not only for ecological balance but also for the sustenance of local communities.

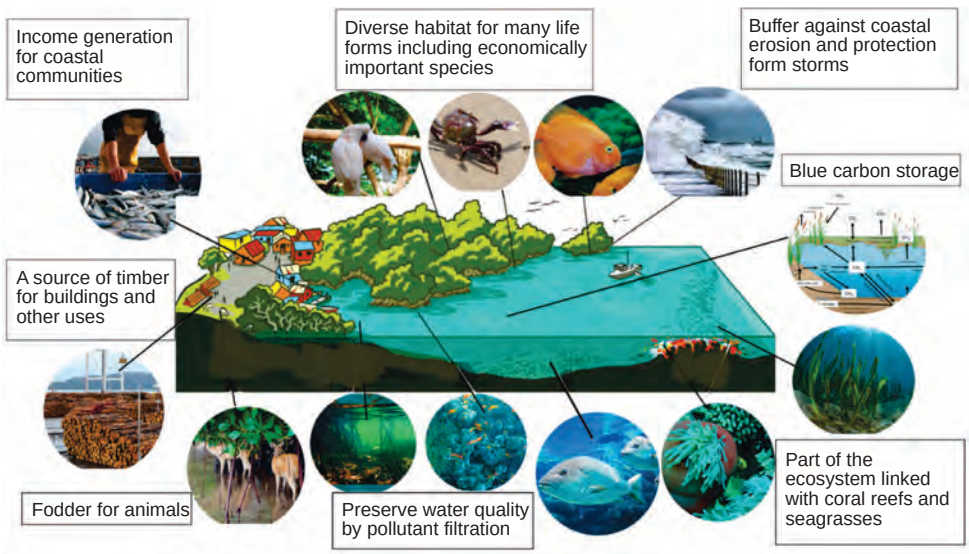

Income generation for coastal communities
Diverse habitat for many life forms including economically important species
Buffer against coastal erosion and protection form storms
Blue carbon storage
A source of timber for buildings and other uses
Fodder for animals
Preserve water quality by pollutant filtration
Part of the ecosystem linked with coral reefs and seagrasses

Fig. 4.8: Functions and Services of an Intact Mangrove Ecosystem

Carbon Sequestration and Climate Change Mitigation

- Mangroves excel in **carbon sequestration,** storing significant amounts of carbon in their biomass and the peat soil beneath, far exceeding the capacity of many other tree species.
- This ability makes them powerful allies in the fight against climate change, helping to mitigate carbon dioxide levels in the atmosphere.
- This process also leads to the accumulation of **"blue carbon,"** which refers to the carbon collected by the world's maritime and coastal ecosystems, emphasising the importance of mangroves in global carbon cycling and climate mitigation efforts.

Water Quality Improvement

- By filtering pollutants and trapping sediments from runoff, mangroves play a vital role in maintaining **water quality**.
- This is essential for the health of adjacent coral reefs and seagrass habitats, which are sensitive to sedimentation and pollution.

Support for Livelihoods and Economy

- Mangroves significantly contribute to the livelihoods of **coastal communities** through **fisheries, wood and non-wood forest products, and tourism.**
- They provide a rich supply of **fish, crabs, and shellfish,** supporting local economies and food security.
- Additionally, mangroves attract tourists, further bolstering local economies.

Climate Adaptation

- Mangroves are key to climate change adaptation, offering a dynamic form of **coastal defence against sea-level rise and increased storm intensity.**
- Their ability to trap sediments allows mangrove areas to grow in elevation, keeping pace with sea-level rise.

Cultural Value

- Mangroves hold immense cultural value for many **indigenous and local communities,** often considered sacred spaces integral to their cultural identity and practices.

Mangroves provide critical environmental services ranging from coastal protection and biodiversity support to climate change mitigation and human community support. Mangrove forest conservation and sustainable management are critical for ensuring that these advantages continue for future generations.

IGNITE YOUR MIND

Salty Sentinels or Sinking Survivors? Mangroves filter pollutants, protect coastlines from storms, and provide vital nursery grounds for marine life. However, rising sea levels and deforestation threaten their existence. Can these "salty sentinels" adapt to survive, or are they destined to become sinking survivors? How can we ensure their future as guardians of the coast?

Threats to Mangroves

Mangroves, which are known for their ecological significance and biodiversity, suffer several risks to their survival and the multitude of services they provide. The MDPI review article discusses these issues in detail, emphasising the critical necessity for appropriate mangrove management techniques.

Stress on Mangroves

- Mangroves are disappearing at a global loss rate of 1–2% per year, and the **loss reached 35% during the last 20 years.**
- Since 1996, the planet's mangrove coverage has declined by 11,700-sq- km, an area thrice the size of Goa—with South and Southeast Asia witnessing the most significant loss.

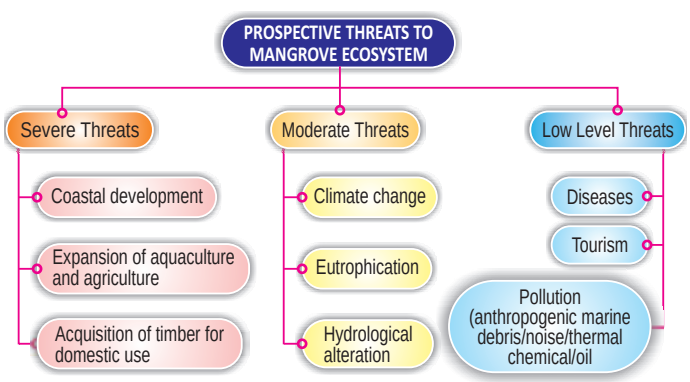


Fig. 4.9: Prospective Threats to Mangrove Ecosystem

Declining Diversity

- According to the **IUCN red list, 11 of the 70 mangrove species** in the world (16 %) are at an elevated threat of extinction. Among them, two species, namely **Sonneratia griffithii** (critically endangered) and **Heritiera fomes** (endangered), are found in India.
- **1,533 species** are associated with mangroves in some way; **15%** of which are threatened with extinction. Nearly **50%** of mangrove-associated mammals, 22% of fishes, 16% of plants, 13% of amphibians and 8% of bird and reptile species are **threatened with extinction.**

Coastal Development

- **Rapid coastal development** is a primary threat to mangroves, leading to habitat loss and fragmentation.
- The expansion of urban areas, industrial activities, and infrastructure projects often results in the clearing of mangrove forests, significantly reducing their coverage and ecological integrity.

Expanded Aquaculture

- The conversion of mangrove areas into **aquaculture ponds,** particularly for **shrimp farming,** has been a significant cause of mangrove loss in many countries.
- This practice not only destroys mangrove habitats but also alters **local hydrology** and water quality, further stressing remaining mangrove areas.

Deforestation

- Deforestation for **timber, agriculture,** and other land uses continues to be a major threat to mangroves.
- The removal of mangrove trees for wood and the conversion of mangrove lands into agricultural fields lead to the depletion of these critical ecosystems.

Climate Change

- Climate change poses multiple threats to mangroves, including **sea-level rise, increased frequency and intensity of storms,** and **changes in salinity levels.**
- These impacts can lead to mangrove dieback, reduced regeneration capacity, and the loss of biodiversity.

Eutrophication, Diseases, and Pollution

- Nutrient runoff from agricultural lands leads to eutrophication, which can cause **harmful algal blooms and oxygen depletion,** affecting mangrove health.
- Diseases and pollution from industrial and domestic sources further degrade mangrove ecosystems.

Land Use Conflict and Inadequate Regulatory Actions

- Conflicts over land use, particularly in **coastal areas** where economic pressures are high, challenge mangrove conservation efforts.

- Inadequate regulatory frameworks and enforcement mechanisms fail to provide the necessary protection for mangrove areas.

Inadequate Policy and Government Frameworks

- The lack of **comprehensive and integrated policy frameworks** for mangrove conservation and sustainable management hinders effective protection and restoration efforts.
- Policies often do not adequately address the complex socio-ecological dynamics of mangrove ecosystems.

Lack of Community Awareness

- A **lack of awareness** and understanding among local communities and stakeholders about the importance of mangroves and the threats they face undermines conservation initiatives.
- Engaging communities in mangrove management is crucial for the success of conservation efforts.

Deforestation, pollution, and climate change pose serious challenges to mangroves, resulting in the rapid loss of these essential coastal ecosystems. Mangrove degradation weakens their critical function in preserving shorelines, maintaining marine biodiversity, and sequestrating carbon, emphasising the urgent need for worldwide conservation efforts to preserve and restore these essential habitats.

IGNITE YOUR MIND

Mangroves and Us: A Connected Future? Our choices regarding climate change, deforestation, and resource consumption directly impact the fate of mangroves. By understanding the intricate connections between human activities and these ecosystems, can we inspire individual and collective action towards a future where mangroves and humans thrive together? How can you personally contribute to safeguarding these vital coastal guardians?

Conservation of Mangroves

Mangroves are significant coastal ecosystems found in tropical and sub-tropical climates and play an important role in safeguarding shorelines, supporting biodiversity, and storing carbon, which makes them critical in the fight against climate change. These ecosystems support a varied range of animals, protect coastal settlements from storm surges and erosion, and provide a source of income for millions of people worldwide. However, mangroves are under threat from deforestation, pollution, climate change and coastal development, demanding comprehensive conservation measures.

Global Initiatives for the Conservation of Mangroves

Global mangrove conservation efforts are increasingly recognised as critical to environmental sustainability, climate change mitigation, and coastal community protection. These activities include a variety of measures for preserving, restoring, and sustainably managing mangrove habitats around the world. These initiatives are based on the notion that mangroves are important not only for biodiversity but also for carbon storage, safeguarding coastlines from erosion and harsh weather events, and supporting the livelihoods of millions of people who rely on them.

- **The Global Mangrove Alliance (GMA):** Launched in **2017**, the GMA aims to increase the global area of mangrove habitats by **20% by 2030.** This alliance is a collaboration between conservation organisations and groups, including the **World Wildlife Fund (WWF), Conservation International,** and **The Nature Conservancy,** among others. The GMA focuses on promoting mangrove conservation, restoration, and sustainable use through international cooperation.
- **The United Nations Environment Programme (UNEP) Global Programme on Mangroves:** UNEP has several initiatives aimed at protecting and restoring mangrove ecosystems. These include providing **technical assistance, promoting best management practices,** and supporting policy development at the national and international levels.
- **The Blue Carbon Initiative:** This global programme focuses on mitigating climate change through the conservation and restoration of **coastal and marine ecosystems, including mangroves.** The initiative recognises the role of mangroves in carbon sequestration and aims to include these ecosystems in global strategies to reduce emissions and promote climate adaptation.
- **Mangroves for the Future (MFF):** It is a partnership-based initiative from **the International Union for Conservation of Nature (IUCN) that** leads and encourages investment in coastal ecosystem conservation for sustainable development. It emphasises the importance of mangroves for coastal resilience, livelihoods and biodiversity conservation.
- **REDD+ (Reducing Emissions from Deforestation and Forest Degradation):** While primarily focused on forests, REDD+ initiatives increasingly recognise the importance of **conserving and restoring mangrove forests** as a strategy to reduce emissions and enhance carbon stocks.
- **The Ramsar Convention on Wetlands:** This international treaty advocates for the conservation and wise use of wetlands, including mangroves. It provides a framework for **national action and international cooperation** for the conservation of wetlands and their resources. Numerous mangrove forests around the world are designated as Ramsar sites, recognising their international importance and promoting their protection.

- **National Strategies and Action Plans:** Many countries with significant mangrove cover have developed national strategies and action plans for mangrove conservation and restoration. These plans often include measures for protected area management, reforestation, and sustainable use practices.

IGNITE YOUR MIND

Balancing Act: Conservation vs. Development? Mangrove ecosystems often hold valuable resources, leading to conflicts between conservation and development. Local communities rely on these resources for their livelihoods, while their removal can have devastating environmental consequences. Can we find a sustainable balance between protecting mangroves and supporting local communities? Explore potential solutions that benefit both people and the environment.

Indian Initiatives for the Conservation of Mangroves

India's commitment to Mangrove conservation demonstrates its attention to environmental sustainability and biodiversity protection. Over the last two decades, the country has seen significant growth in mangrove cover, thanks to a comprehensive strategy that combines regulatory measures and promotional campaigns.

Promotional Measures

- **Central Sector Scheme on Conservation and Management of Mangroves and Coral Reefs:** This scheme, part of the **National Coastal Mission Programme,** supports coastal states and union territories in implementing action plans that include survey and demarcation, alternative livelihood options, protection measures, and education and awareness activities. It aims to sustain, conserve and augment mangrove forests through various initiatives.
- **State-Level Initiatives:** Notably, the State **Government of Maharashtra** has taken significant steps by forming a **dedicated mangrove cell** for conservation efforts and creating a **mangrove and Marine Biodiversity Conservation Foundation.** These initiatives focus on mangrove and marine conservation, research, and livelihood activities. Similarly, **Kerala's "Kannur Mangrove Mission"** has led to the notification of **2.36 km² of mangroves as 'Reserved Forest',** enhancing protection and afforestation efforts.
- **Research Support:** The **central and state governments** encourage and support research by academic institutions aimed at the development and conservation of mangrove ecosystems, fostering innovation and effective conservation strategies.

Regulatory Measures

- **National Mangroves Committee:** Established in **1976,** this committee within the **Ministry of Environment and Forests** advises the government on the conservation and development of mangroves across India, emphasising the importance of mangrove ecosystems.
- **Environment (Protection) Act, 1986:** The **Coastal Regulation Zone (CRZ)** Notification issued under this act restricts industrial activities, untreated water discharge, waste dumping, land reclamation, and bunding in coastal areas, including mangroves, to protect these critical ecosystems.
- **National Forest Policy, 1988:** This policy identifies the conservation and **management of natural forest ecosystems,** including mangroves, as a priority area for forestry research, underscoring the ecological significance of mangroves.
- **Management Action Plans:** The Government of India provides guidance and to states and Union Territories for the preparation and implementation of Management Action Plans focused on the conservation and development of mangrove ecosystems.

Achievements and Progress

- **Mangrove Growth:** From **2001 to 2021,** India's mangrove cover **increased by 510 km^2,** with a **net increase of 17 km^2** since the **2019 assessment.** This growth is a result of both legislative protections and proactive afforestation efforts that have facilitated natural colonization.
- **Afforestation Efforts:** In **Gujarat, 490 km^2** of mangrove area has been afforested through government initiatives and **Public-Private Partnerships** involving communities. The **Integrated Coastal Zone Management (ICZM)** Project has contributed to large-scale afforestation in **Gujarat (195.03 km^2), Odisha (3.23 km^2), and West Bengal (1.18 km^2).**
- **International Recognition:** Significant mangrove areas like the **Indian Sunderbans, Bhitarkanika, and Pichavaram** have been declared as **Ramsar Sites,** acknowledging their global ecological importance.
- **National Scheme and International Collaboration:** The **MoEF&CC** provides dedicated budgetary support for the conservation and management of mangroves and coral reefs. India's participation in the **Mangroves For the Future (MFF)** initiative by the **IUCN** underscores its commitment to international mangrove conservation efforts.

Mangrove Initiative for Shoreline Habitats & Tangible Incomes (MISHTI)

- The Union Budget for **2023-24** has notably emphasized the importance of mangroves in India by announcing the **MISHTI,** aimed at mangrove plantation along the coastline and on salt pan lands.

- This initiative underscores the critical role of mangroves in environmental protection and climate change mitigation.

MISHTI Implementation

- The MISHTI initiative will be implemented through convergence between the **Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) Fund,** and other sources.
- This approach emphasizes the importance of working with local communities for the successful establishment and growth of mangrove plantations.
- The survival rates for mangrove seed plantations and saplings highlight the challenges in mangrove restoration, underscoring the need for ongoing care and community involvement.

Way Forward for Mangroves Conservation

The conservation of mangroves is critical for maintaining ecological balance, protecting coastal communities, and preserving biodiversity. A multifaceted approach is necessary to ensure the effective conservation and restoration of mangrove ecosystems.

- **Strengthening Legal Frameworks:** Implement and enforce **strong legal protections** for mangrove ecosystems at both national and international levels. This includes designating mangrove areas as protected reserves and integrating mangrove conservation into broader environmental and coastal management policies.
- **Community Engagement and Livelihoods:** Involve local communities in mangrove conservation efforts by promoting sustainable livelihoods that are dependent on the health of mangrove ecosystems. Empowering communities through education and providing alternatives to mangrove-destructive practices can foster local stewardship.
- **Restoration and Rehabilitation:** Implement mangrove restoration projects in areas where mangroves have been degraded or destroyed, using scientifically sound and locally adapted reforestation techniques. Promote the use of **mangrove-friendly aquaculture** practices to reduce the impact of shrimp farming and other aquaculture activities on mangrove areas.
- **Research and Monitoring:** Enhance research on mangrove ecology to better understand their role in carbon sequestration, coastal protection, and supporting biodiversity. This knowledge can inform more effective conservation and management strategies.
- **Climate Change Mitigation and Adaptation:** Integrate mangrove conservation into **climate change mitigation and adaptation strategies.** Recognising mangroves as vital carbon sinks and as natural barriers against storm surges and coastal erosion can secure funding and support for their conservation.

By adopting these strategies, we can ensure the protection and sustainable management of mangrove ecosystems, securing their invaluable benefits for the environment, biodiversity, and human communities. The way forward for mangrove conservation requires a collective effort from governments, NGOs, communities, and international bodies to safeguard these critical ecosystems for future generations.

CORAL REEFS: OCEANIC MARVELS

Coral reefs are generally regarded as **maritime wonders,** grab the mind with their bright colours and thriving life. These underwater environments are not only visually breathtaking, but also have incredible biological complexity and ecological significance. Coral reefs, known as the **"rainforests of the sea,"** are biodiversity hotspots that support an incredible diversity of marine animals. Their elaborate structures, created over millennia by microscopic coral polyps, serve as the foundation for one of Earth's most productive and dynamic habitats.

Corals

Fig. 4.10: Corals

- Corals are **marine invertebrates** within the class Anthozoa of the **phylum Cnidaria.** They typically live in compact colonies of many identical individual polyps.
- Corals are composed of thin plates, or layers, of **calcium carbonate** secreted over time by these soft-bodied organisms known as **coral polyps.**
- These polyps range in size from a pinhead to up to a foot in length and engage in a symbiotic relationship with **zooxanthellae,** algae that reside within the corals, **giving them their vibrant colors.**
- The zooxanthellae perform **photosynthesis,** producing **oxygen** and other nutrients vital for the survival of coral polyps, which in turn necessitates that corals reside in shallow, clear waters where sunlight is abundant.
- **Types of Corals:** Corals are categorised into two main types i.e hard and soft.
  - **Hard Corals (Scleractinia):** These include species such as **brain, star, staghorn, elkhorn, and pillar corals.** They possess rigid **exoskeletons, or corallites,** which serve to protect their soft bodies.
  - **Soft Corals (Gorgonians):** Examples include **sea fans, sea whips, and sea rods.** Unlike hard corals, soft corals are flexible and move with the currents, lacking a hard exoskeleton.

Coral Reefs

- Corals are the foundational organisms of coral reefs, creating the very structure that defines these ecosystems.
- Through a **symbiotic relationship with zooxanthellae,** tiny algae that live **within their tissues,** corals perform **photosynthesis,** providing energy for the reef's growth and development.
- As corals grow, they secrete calcium carbonate skeletons, which accumulate over time to form the complex, three-dimensional structures of coral reefs.

Ideal Conditions for Coral Formation

The ideal conditions for coral creation comprise a combination of environmental elements that promote the growth and development of coral polyps, the microscopic organisms that produce coral reefs. The conditions are:

- **Warm Water Temperatures:** Corals thrive in water temperatures ranging from **23°C to 29°C (73°F to 84°F).** Most coral species are found in **tropical and subtropical waters** where temperatures are stable and conducive to their growth.
- **Clear, Sunlit Waters:** Corals require sunlight for **photosynthesis,** performed by the symbiotic algae (zooxanthellae) living within their tissues. Clear waters allow sunlight to penetrate to the depths where corals grow, typically **not deeper than 50 meters (about 164 feet).**
- **Saline Conditions:** Corals **need saltwater to survive,** with an ideal salinity range of **32 to 42 parts per thousand.** This salinity level supports the osmotic balance necessary for coral health.
- **Stable Conditions:** Corals benefit from stable environmental conditions **without extreme changes in temperature, salinity, or water chemistry.** Sudden shifts can stress coral communities and lead to bleaching events.
- **Clean Water:** Corals require clean waters. **Excessive nutrients** from agricultural runoff or sewage can lead to **algal blooms** that block sunlight and harm corals.
- **Hard Substrate:** For the attachment and growth of coral larvae, a hard, stable substrate is necessary. This allows corals to **anchor** themselves and begin the process of building reefs.
- **Low Sedimentation:** High levels of sediment in the water can **smother corals, blocking sunlight** and hindering their growth. Ideal coral habitats have low rates of sedimentation.

All of these factors work together to produce an ideal habitat for corals to thrive and coral reefs to grow and expand, hence supporting the ecosystems' rich biodiversity.

Types of Coral Reefs

Coral reefs, celebrated for their ecological significance and breathtaking beauty, are categorised into three distinct types: fringing reefs, barrier reefs, and atoll reefs. Each type plays a crucial role in marine biodiversity and provides essential ecosystem services.

Fringing Reefs

- These reefs are characterised by two main parts: **The reef flat, which is closest to shore, and the reef slope, which faces the open ocean and hosts most of the marine life.**
- The coral reefs around the **Andaman and Nicobar Islands** are pre-dominantly fringing reefs. These reefs are directly attached to the shore, creating a narrow band of coral structures that fringe the islands.

Barrier Reefs

- Similar to **fringing reefs, barrier reefs are found near shore but are separated from the land by a deep-water lagoon,** forming a barrier between the coast and the open ocean.
- The most famous barrier reef is the **Great Barrier Reef off the coast of Australia,** which is a chain of smaller barrier reefs.

Atoll Reefs

- Atolls are rings of coral reefs located in the open ocean, often taking a **horse-shoe** shape with a lagoon in the centre.
- They form when fringing reefs grow around **volcanic islands** that eventually subside into the ocean.
- The **Lakshadweep Islands** are known for their **atoll formations.** These coral atolls are circular or oval rings of coral that enclose a lagoon.

Development of Major Coral Reef Types

Understanding coral reef growth necessitates a systematic investigation of **geological and biological** processes. Coral reefs, which are noted for their **richness and ecological importance,** evolve in a sequence of stages over thousands to millions of years. The following is a detailed, step-by-step description of how the **three types of coral reefs—fringing reefs, barrier reefs, and atolls**—form.

Coral Polyp Settlement and Reef Formation

- **Initial Settlement:** The process begins with **coral larvae settling on hard substrates** along the edges of islands or continents. These larvae originate from coral spawning events and seek suitable locations to attach and grow.
- **Coral Polyp Growth:** Once settled, the coral larvae **metamorphose** into polyps, which secrete **calcium carbonate (limestone)** to build protective skeletons around themselves. Over time, these skeletons accumulate, forming the **reef structure.**

- **Symbiotic Relationship:** Coral polyps enter into a **symbiotic relationship** with **zooxanthellae, microscopic algae** that live within their tissues. The **zooxanthellae** perform photosynthesis, providing nutrients to the coral, which **in turn offers the algae a protected environment** and access to sunlight.

Development of Fringing Reefs

- **Proximity to the Shore:** Fringing reefs form **close to the shoreline and are the first stage** in the coral reef development process. They grow **seaward directly** from the shore, creating a narrow reef flat that extends outwards.
- **Lagoon Formation:** In some cases, a **shallow lagoon** may form between the fringing reef and the shore, but often, fringing reefs are **directly attached to the coastline** without a significant lagoon.

Transition to Barrier Reefs

- **Lagoon Expansion:** Over time, **geological activity,** sea-level changes, and the continuous growth of coral can lead to the **widening of the lagoon** between the fringing reef and the shore. This process can take thousands of years.

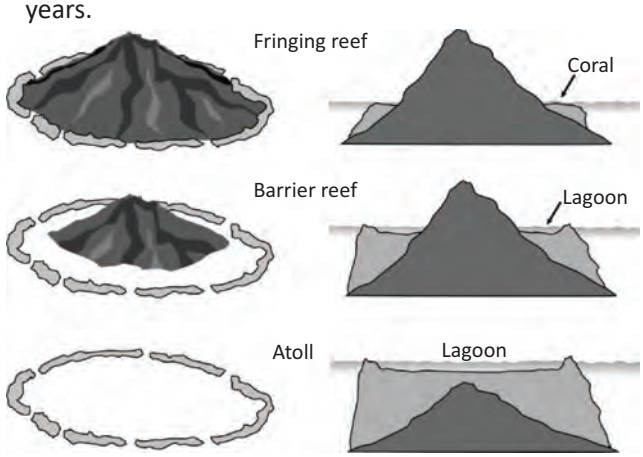


Fig. 4.11: Development of Major Coral Reefs

- **Barrier Reef Formation:** As the lagoon **widens and deepens,** the reef becomes a barrier reef. This type of reef is characterised by its **separation from the mainland or island** by deep water, which forms a protective barrier against waves and storms.

Atoll Formation

- **Island Subsidence:** The formation of an atoll begins with a **volcanic island** that **sinks slowly back into the ocean over millions of years** due to geological processes and the weight of the built-up coral reef.
- **Reef Growth:** While the island subsides, the coral reef continues to grow upwards towards the sunlight, **maintaining its position** at the water's surface.
- **Atoll Completion:** Eventually, the **original island disappears** below the sea surface, leaving behind a **ring-shaped reef surrounding a central lagoon.** The atoll is the final stage in this natural progression of coral reef development.

Ecological Succession

- **Biodiversity Increase:** Throughout these stages, the developing reef structure provides habitats for a diverse array of marine life, leading to ecological succession and increased biodiversity within the reef ecosystem.

Global Distribution of Corals

Distribution of Coral Reefs: Coral reefs are found in **109 countries around the world,** primarily within three regions between **20 degrees north and 20 degrees south of the equator: The Indo-Pacific, the Western Atlantic, and the Red Sea.**

- **The Indo-Pacific Region:** It extends from **South-east Asia through Polynesia and Australia,** across the **Indian Ocean to Africa.** This region hosts the largest and most diverse collection of reefs.
- **The Western Atlantic Region:** It spans from **Florida to Brazil,** encompassing **Bermuda, the Bahamas, the Caribbean, Belize, and the Gulf of Mexico.**
- **The Red Sea:** It stands out for having a distinctive coral reef ecosystem being located between **Africa and Saudi Arabia.**

Cold Water-Corals

- Cold water corals have been a part of our oceans for **millions of years,** spreading across all seas and oceans globally.
- These unique marine invertebrates belong to the **Phylum Cnidaria** and are characterised by their **calcareous skeletons,** distinguishing them from their tropical counterparts.
- Unlike tropical corals, cold water corals thrive in **deep, cold, and dark environments,** ranging from **40 meters to over 1000 meters deep,** where **temperatures hover between 4° and 13°C.**
- The **absence of symbiotic algae** in their tissues means these corals **rely on organic matter, particularly zooplankton,** for nourishment, necessitating marine currents for the distribution of nutrients.

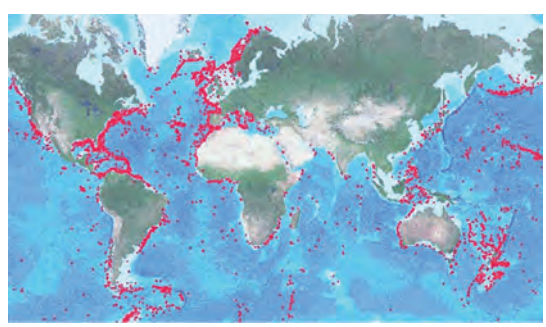


Fig. 4.12: Global Distribution of Cold Corals

- **Distribution**
  - Cold water corals are found in diverse locations around the world, from the **Norwegian continental shelf,** known for its high biodiversity, to the **Atlantic coast** stretching to the **Canary Islands, the Azores, and Madeira.**

- The most common species include **Desmophyllum pertusum and Madrepora oculata,** which form complex habitats supporting a myriad of marine life such as sponges, crustaceans, mollusks, and fish.
- These ecosystems are crucial for the biodiversity of the oceans, offering refuge and breeding grounds for various species.

Coral Reefs in India

- India, with its extensive coastline of **over 8,000 km** and **subtropical climatic conditions,** hosts all three major types of coral reefs: Atoll, fringing, and barrier reefs.
- Despite the vast coastline, coral reef areas in India are relatively few compared to other regions of the world. However, the reefs that do exist are among the **most diverse, extensive, and least disturbed,** offering a unique glimpse into the underwater biodiversity of the Indian subcontinent.
- Many of these reefs remain largely unstudied, holding secrets to the marine life that thrives within them.

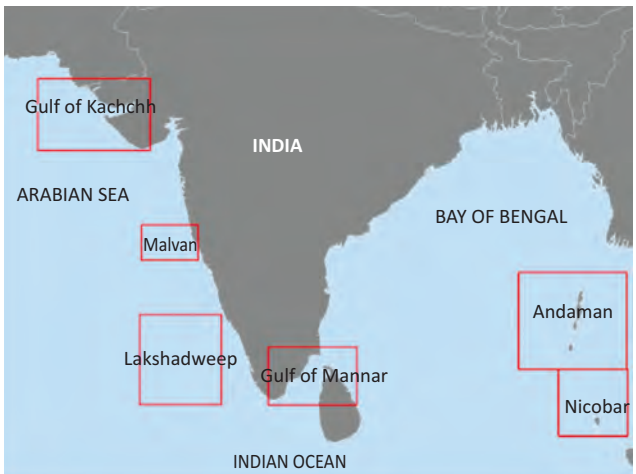


Fig. 4.13: Distribution of Coral Reefs Across Indian Coastline.

Distribution and Status of Coral Reefs in India

Location	Status of Coral Reefs	Research Focus	Perceived Threats	Types of Coral Reefs
Palk Bay	Coral reefs are slowly recovering from the coral mining activities of the 1960s.	Focuses mainly on bio-physical aspects and the impact of population pressure and its associated effects.	Population pressure and its associated effects pose significant threats.	Hosts fringing reefs, which are directly adjacent to the shore, creating rich habitats for marine life.
Gulf of Mannar	Experiencing a slow recovery from the coral mining of the 1960s.	Research is centered on bio-physical aspects, associated fauna, and the impact of human activities on the reefs.	Threatened by population pressure and its associated effects.	Features fringing reefs similar to those in Palk Bay, which contributes to the area's biodiversity.
Andaman & Nicobar	The status ranges from fair to excellent, with some issues around the south island.	Targets bio-physical aspects, associated fauna, and the impact of human activities on the reefs.	Siltation due to logging and sand mining is a major threat.	Surrounded by fringing reefs and boasts a long barrier reef (329 km) on the West coast, among the most diverse and pristine reefs in India.
Lakshadweep	Reefs off uninhabited islands are in excellent condition, but those along habitable islands are endangered.	Also concentrates on bio-physical aspects, associated fauna, and the impact of human activities.	Faces threats from population pressure and its associated effects.	Known for their atoll reefs, featuring extensive reef growth, though these areas are also poorly explored.
Gulf of Kutch	Only 30% of the coral reefs are living.	Focuses on bio-physical aspects, associated fauna, and the impact of human activities on the reefs.	Threatened by sedimentation and siltation due to the cutting of mangrove forests and sand mining for industrial use, alongside population pressure.	Home to some of the most northerly reefs in the world, featuring unique platform reefs due to their geographical location.

New Species of Corals in India

- Scientists have recently identified four new species of **azooxanthellate corals in the Andaman and Nicobar Islands,** marking a significant discovery for Indian marine biodiversity.
- These species, which do not contain the symbiotic algae zooxanthellae and derive nourishment from plankton, include:
  - **Truncatoflabellum crassum**
  - **Truncatoflabellum aculeatum**
  - **Truncatoflabellum incrustatum**
  - **Truncatoflabellum irregulare**
- Belonging to the family **Flabellidae,** these corals were previously known from regions ranging from Japan to the Philippines and Australian waters.
- This research enhances the national database of biological resources and underscores the critical role of coral reefs, which support a vast array of marine life despite covering less than **1%** of the Earth's surface.

IGNITE YOUR MIND

Beyond Beauty: Coral reefs are not just stunning; they play a critical role in the health of our oceans. Discover the diverse benefits they provide, from protecting coastlines to supporting marine biodiversity, and understand why they are considered essential for the underwater world.

Importance of Corals

Coral reefs, which are sometimes compared to **undersea towns,** are not only visually appealing but also play an important role in **marine and coastal ecosystems.** Their significance extends far beyond the enjoyment they provide to people who investigate their vibrant fish, complicated patterns, and **wonderful sea animals.** Here's a detailed look at the value of coral reefs:

A Barrier from Storms and Surge

- Storm surge is a **sudden increase in water level** that occurs during **tropical storms, hurricanes, or typhoons.** It is a coastal flood or tsunami-like phenomenon that is often linked to low-pressure weather systems.
- Coral reefs, particularly **barrier reefs like Florida's,** serve as **natural defences against storms and surge water.**
- They reduce wave impact and buffer shores, **stabilising mangroves and seagrass** beds that are vulnerable to **strong currents and waves.**
- This erosion prevention is crucial in areas like the Florida Keys, where residential and commercial structures line the shore.

Biodiversity Hotspots

- Coral reefs occupy less than one percent of the ocean floor but are home to **more than 25% of all marine life.**
- Coral reefs are foundational to complex food webs, supporting an **incredible diversity of fish.**
- The ecosystem includes **algae, soft corals, sponges, and invertebrates** at its base, supporting everything from small herbivorous fish to large predators.
- Beyond fish, reefs host a diverse array of marine crustaceans, reptiles, and mammals, including **lobsters, octopuses, sea turtles, and dolphins.**
- These animals rely on the reef for food, habitat, and protection, contributing to the balanced marine ecosystem that is rich and abundant with life.

Source of Novel Pharmaceuticals

- **Bioactive Compounds:** Coral reefs are home to a vast array of organisms that produce **bioactive compounds** as defence mechanisms against predators. These compounds are being studied for their potential applications in treating diseases and health conditions. For example, certain coral reef species produce substances with **anti-inflammatory, antibacterial, antiviral, and anticancer properties.**
- **Cancer Research:** Compounds derived from coral reef organisms have shown **promise in cancer research.** For instance, **Yondelis (trabectedin),** a drug used in the treatment of soft tissue **sarcoma and ovarian cancer,** is derived from a compound found in a **sea squirt,** a marine organism that **inhabits coral reefs.**
- **Pain Management: Cone snails,** which live in coral reef ecosystems, produce **venom** that has been studied for its **potential in pain management. Ziconotide,** derived from **cone snail venom,** is an example of a novel pain relief medication that targets pain pathways differently than traditional drugs, offering new hope for patients with severe chronic pain.
- **Bone Grafts and Regeneration:** The structural similarity of coral to human bone has led to the use of **coral-derived materials in bone grafts and orthopaedic surgeries.** Corals' porous structure promotes bone cell growth and attachment, making them excellent materials for bone repair and regeneration.

Source of Nutrition

- For coastal populations, fish and other marine life harvested from coral reefs have been a primary **protein source** for millennia.
- Fisheries, from small-scale artisanal to major commercial operations, depend on reefs for **spawning and habitat.**
- Species like lobster, stone crab, snapper, and grouper directly rely on reefs, while others, such as **tuna and dolphin,** depend on the reef indirectly through their prey.

Water Filtration

- **Corals and sponges** play a significant role in **water filtration,** consuming particulate matter suspended in the water.
- This natural filtration process enhances the quality and clarity of nearshore waters, contributing to the overall health of marine environments.

Economic Development

- Coral reefs underpin the economies of many regions, **attracting tourists for diving and related activities.**
- This **tourism** demand supports not only dive operations but also local businesses, including restaurants, hotels, and entertainment facilities.
- While tourism can transform local economies, it also poses challenges, such as potential environmental impacts from unregulated tourist activities.

Artificial Reef

- An artificial reef is a man-made structure designed to mimic some characteristics of a natural reef.
- These structures can range from submerged shipwrecks to oil and gas platforms, bridges, lighthouses, and other offshore structures.

- Marine resource managers create artificial reefs in underwater areas lacking natural reef structures to enhance habitat for reef organisms, including corals and the diverse marine life that depends on them.
- These reefs provide essential habitats for marine species and have become popular attractions for commercial and recreational fishing, diving, and snorkeling, contributing to local economies.
- However, the creation of artificial reefs can lead to environmental challenges, including illegal dumping and poaching.

Coral reefs are critical to the health of our planet's oceans, as they provide protection, biodiversity, and economic advantages to human societies. Their conservation is critical to preserving these benefits and ensuring the long-term viability of maritime habitats.

IGNITE YOUR MIND

Tourism: Boon or Bane? Is tourism a double-edged sword for fragile ecosystems like coral reefs? Can responsible eco-tourism practices benefit both local communities and these underwater wonders? Unravel the complex relationship between tourism and conservation, and discover how to navigate this tricky terrain.

Coral Bleaching

Coral bleaching is a phenomenon that occurs when coral reefs are under **environmental stress, resulting in the loss of vivid colours and potentially causing substantial harm to these ecosystems.** The following is a full, **step-by-step description of coral bleaching:**

Coral and Zooxanthellae Symbiosis

- **Symbiotic Relationship:** Coral polyps live in a **mutualistic relationship with microscopic algae called zooxanthellae.** These algae reside within the coral's tissues, providing the coral with up to **90% of its energy needs through photosynthesis.** In return, corals offer zooxanthellae a protected environment and the compounds necessary for photosynthesis.

Environmental Stressors Trigger Bleaching

- **Temperature Stress:** The primary cause of coral bleaching is an **increase in water temperatures,** often due to **global warming and climate change.** Other stressors can include **solar irradiance (UV light and visible light), low ocean pH (ocean acidification), pollution, and changes in salinity.**
- **Stress Response:** Corals respond to stress by expelling the zooxanthellae from their tissues as a result of changes in conditions, **particularly temperature.** This loss results in a significant reduction in the coral's ability to obtain energy.

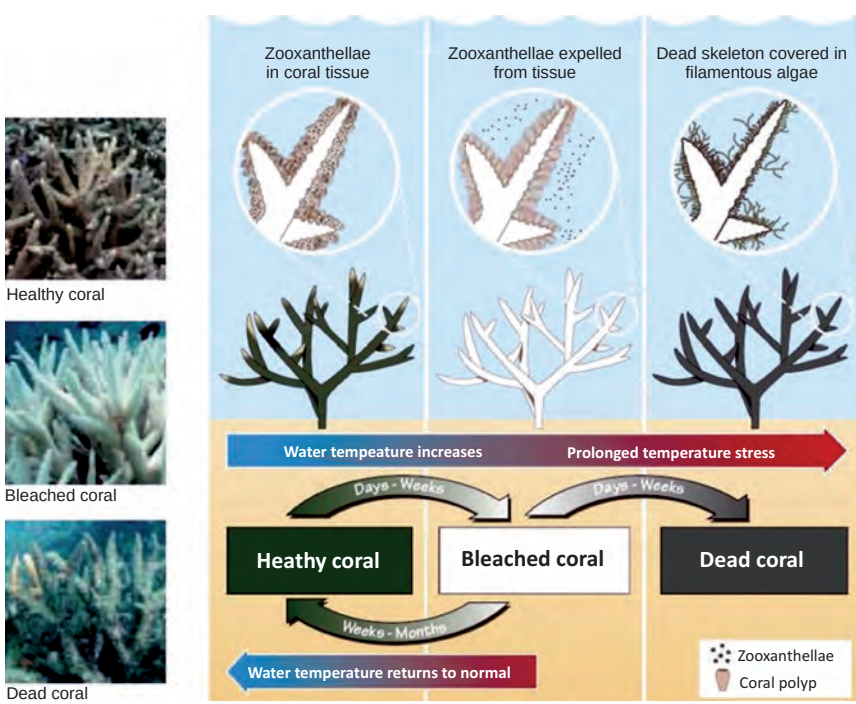


Fig. 4.14: Stages in Mass Coral Bleaching

The Bleaching Event

- **Appearance:** Without the zooxanthellae, the coral tissues become **transparent,** revealing the **white calcium carbonate skeleton** beneath. This is why the phenomenon is termed **"bleaching."** Although corals can survive a bleaching event, their growth, reproduction, and overall health are severely impacted.

- **Example:** The Great Barrier Reef witnessed mass bleaching events in 1998, 2002, 2016, 2017, 2020, and 2022. Bleaching affected 91% of the reef in 2022, and it was the first time on record the reef had suffered bleaching during a La Nina weather cycle.

Potential Recovery or Mortality

- **Recovery: If favourable conditions return promptly,** corals can recover from a bleaching event. They can **reabsorb zooxanthellae,** either from the surrounding water or by dividing the remaining zooxanthellae within their tissues, and regain their colour and health over time.
- **Mortality: Prolonged stress conditions,** however, can lead to the coral's death. **Without zooxanthellae, corals eventually starve,** weakening their ability to combat diseases and maintain the structural integrity of the reef.

Marine Heatwaves

Marine heatwaves are characterized by **prolonged periods of abnormally high sea surface temperatures.**

Causes of Marine Heatwaves

- **Carbon Pollution:** The primary driver of marine heatwaves is the mining and burning of fossil fuels, which releases carbon pollution into the atmosphere. This pollution is a major contributor to global warming, affecting terrestrial and marine environments alike.
- **Ocean Warming:** As a result of increased atmospheric temperatures, the ocean absorbs excess heat, leading to a rise in sea surface temperatures. Since 1900, the ocean's temperature has warmed by approximately 1°C, a change that, while seemingly small, has profound effects on marine life.
- **Sensitivity of Corals:** Corals are particularly sensitive to changes in temperature. A rise of just 1°C above the average can stress coral organisms, making them more susceptible to bleaching and disease.

Impacts of Marine Heatwaves on Coral Reefs

- **Coral Stress and Bleaching:** Elevated ocean temperatures during marine heatwaves cause corals to become stressed, leading to mass coral bleaching events. Bleaching occurs when corals, under stress, expel the symbiotic algae (zooxanthellae) living in their tissues, losing their color and main source of nutrition.
- **Duration and Recovery:** Marine heatwaves can persist for weeks, months, or even years. If ocean temperatures remain elevated for eight weeks or longer, corals are unlikely to recover. Prolonged exposure to high temperatures can result in widespread coral mortality, as the corals are unable to sustain their basic functions or support the zooxanthellae algae.
- **Ecosystem Collapse:** The death of coral organisms following prolonged marine heatwaves leads to the degradation of coral reef ecosystems. These ecosystems are biodiversity hotspots and provide critical services, including coastal protection, habitat for marine life, and resources for local human communities.

Natural Causes of Coral Bleaching

Coral bleaching, which occurs when corals lose their vivid colours and turn white, is mostly caused by environmental factors. While human-caused variables such as Climate Change and pollution are key contributions, natural reasons also play an important part in coral bleaching occurrences. Understanding the natural causes is critical to effective coral reef management and conservation.

Elevated Sea Temperatures

- **Solar Irradiance: Increased solar irradiance can raise sea surface temperatures.** Natural fluctuations in solar output can lead to periods of intensified sunlight, contributing to the warming of ocean waters surrounding coral reefs.
- **El Niño and La Niña Events:** These are natural climate phenomena that cause significant **variations in sea surface temperatures. El Niño events,** in particular, are associated with **warmer ocean temperatures,** which can induce widespread coral bleaching.

Changes in Ocean Currents

- Natural variations in **ocean currents can alter sea temperatures** in coral habitats. Changes in currents may bring warmer waters to coral reef areas, stressing corals and leading to bleaching.

Volcanic Activity

- **Underwater volcanic eruptions** and above-ground volcanic activity can release **vast amounts of particulate matter and gases** into the atmosphere and ocean, affecting **water temperatures and light penetration.** This can create localised hot spots or reduce sunlight, stressing corals and potentially causing bleaching.

Low Tides and Exposure

- During **extremely low tides,** corals may be exposed to the air, sunlight and higher temperatures for prolonged periods. This exposure can lead to thermal stress and **desiccation (drying out),** which in turn, contributes to coral bleaching.

Salinity Changes

- Natural fluctuations in **salinity,** due to factors like freshwater influx from heavy rains or the melting of ice, can stress coral systems. Corals are sensitive to changes in salinity, and significant deviations from their optimal salinity range can lead to bleaching.

Storms and Cyclones

- While storms and cyclones can cause **physical damage to reefs,** they can also lead to coral bleaching. The mixing of water layers during a storm can bring colder water to the surface, causing thermal stress to corals accustomed to stable, warm conditions.

Understanding the natural causes of coral bleaching is critical for distinguishing between human-caused and natural stressors on coral reefs. This understanding aids in the development of specific conservation strategies that address both sets of concerns.

Anthropogenic Causes of Coral Bleaching

Anthropogenic, or human-caused, coral bleaching has played a substantial role in the global loss of coral reef health. Unlike natural causes, which are part of the Earth's climatic and geological cycles, anthropogenic causes are directly related to human actions that affect the marine environment, causing stress and bleaching in coral reefs.

Global Warming and Climate Change

- **Elevated Sea Temperatures:** The primary anthropogenic cause of coral bleaching is global warming, that results from **increased greenhouse gas emissions due to the burning of fossil fuels,** deforestation, and industrial processes. As greenhouse gases accumulate in the Earth's atmosphere, they trap more heat, leading to a rise in global temperatures, including sea surface temperatures. Corals are highly **sensitive to temperature changes,** and even a slight increase can disrupt the symbiotic relationship with zooxanthellae, leading to bleaching.

Ocean Acidification

- **Increased CO_2 Levels:** The **ocean absorbs a significant portion of the carbon dioxide (CO_2)** emitted into the **atmosphere.** This absorption leads to ocean acidification, a process that **decreases the pH level of seawater.** Acidic conditions hinder the ability of corals to produce calcium carbonate, essential for their skeletal structure, and can exacerbate the stress on coral reefs, making them more susceptible to bleaching.

Pollution

- **Chemical Pollutants: Runoff from agriculture, untreated sewage, and industrial waste** introduces harmful chemicals and nutrients into coastal waters. These pollutants can lead to eutrophication, promoting excessive algae growth that blocks sunlight essential for coral health and further stresses coral reefs.
- **Plastics and Marine Debris:** Plastics and other forms of marine debris can **physically damage coral reefs** and, in some cases, release toxic substances as they degrade, contributing to coral stress and bleaching.

Overfishing and Destructive Fishing Practices

- **Ecosystem Imbalance:** Overfishing can lead to **imbalances in the marine ecosystem,** removing key species that help maintain the health of coral reefs. Destructive fishing practices, such as the use of **fishing trawlers,** not only kill fish but also cause direct physical damage to coral structures, increasing their vulnerability to bleaching.

Coastal Development

- **Habitat Destruction:** Coastal development for tourism, urban expansion and infrastructure projects can lead to the direct destruction of coral habitats. Activities associated with development, such as **dredging and land reclamation,** can increase sedimentation, reducing water quality and light availability for corals, thereby stressing them and leading to bleaching.

Unsustainable Tourism

- **Physical Damage and Pollution: Heavy tourist traffic** and irresponsible tourism practices can result in physical damage to coral reefs through trampling, boat anchoring, and the collection of coral. Additionally, the **increased use of sunscreens containing chemicals** harmful to corals can contribute to their stress and bleaching.

Addressing the anthropogenic causes of coral bleaching requires worldwide cooperation and concentrated efforts to reduce greenhouse gas emissions, implement sustainable fishing and coastal management techniques, and raise awareness about the importance of coral reefs and the risks they face. Conservation activities and regulations aimed at reducing human effects on the environment are critical for the preservation and recovery of coral reef systems.

Impact of Coral Bleaching

Coral bleaching has serious and far-reaching consequences for coral reef ecosystems, marine biodiversity, and human societies that rely on the health of these underwater environments. Below is a detailed look at the impact of coral bleaching:

Ecological Impacts

- **Loss of Biodiversity:** Coral reefs are among the most biodiverse ecosystems on the planet. Bleaching events can lead to significant **mortality in coral populations,** which in turn affects the species that depend on them for food, shelter, and breeding grounds. The loss of coral can lead to a **decrease in marine biodiversity,** disrupting the balance of reef ecosystems.
- **Altered Ecosystem Functions:** Healthy coral reefs provide essential ecosystem services, including **nutrient cycling and carbon sequestration.** Bleached and **dying reefs** are less effective at performing these functions, which can have cascading effects on the overall health of the marine environment.

- **Habitat Degradation:** Coral reefs structure the physical environment of marine habitats. **Bleaching weakens coral structures,** making them more susceptible to **erosion and breakage.** This can lead to the **collapse of reef structures,** reducing the complexity of habitats available to marine organisms, and altering the dynamics of reef communities.

Economic Impacts

- **Fisheries Decline:** Many **commercial and subsistence fisheries** depend on coral reefs for key species throughout their life cycles. The decline of coral reefs due to bleaching can lead to **reduced fish stocks, impacting food security and livelihoods** for coastal communities.
- **Tourism Losses:** Coral reefs attract **millions of tourists each year,** contributing significantly to the economies of many **tropical countries.** Bleaching events can diminish the **aesthetic value of reefs,** leading to a decrease in tourism revenue. This can have a ripple effect on local economies, affecting businesses and employment opportunities.

Social and Cultural Impacts

- **Food Security:** Coastal communities often rely on reef-associated fish and **invertebrates as a primary source of protein.** The decline in reef health and associated fish stocks can lead to food insecurity and nutritional deficiencies in these populations.
- **Cultural Loss:** For many indigenous and coastal communities, **coral reefs hold cultural significance and are integral to their way of life and identity.** The degradation of reefs can lead to the loss of cultural heritage and practices that have been sustained for generations.

Global Implications

- **Climate Change Feedback Loops:** Coral reefs play a role in regulating carbon dioxide levels in the ocean. Their decline can exacerbate the effects of climate change by **reducing the ocean's capacity to absorb CO_2,** contributing to a feedback loop that further accelerates global warming.
- **Loss of Biodiversity Hotspots:** Coral reefs are hotspots of marine biodiversity. Their decline threatens the **extinction of numerous species,** many of which are not yet discovered or fully understood. This loss of biodiversity can have unknown consequences for the resilience and function of marine ecosystems.

The prevalent effects of coral bleaching underscore the interconnection of ecological, economic, and social systems, as well as the significance of protecting coral reefs for future generations.

Case Study: Cryogenic Preservation of Great Barrier Reef Coral

In a pioneering effort to combat the effects of climate change on coral reefs, scientists have successfully trialed a new method for the cryogenic preservation of coral larvae from Australia's Great Barrier Reef. Utilizing a novel **"cryomesh" technology,** this approach allows for the freezing of coral larvae at -196°C, offering a cost-effective and efficient solution for coral conservation. This trial, conducted at the Australian Institute of Marine Sciences (AIMS), represents a significant breakthrough in reef restoration efforts, potentially providing a scalable solution to preserve coral biodiversity and aid in the rewilding of threatened reefs. The development of cryomesh technology, led by a team from the University of Minnesota, marks a promising step forward in safeguarding the future of coral reefs against the backdrop of rising ocean temperatures and bleaching events.

Global Initiatives for the Conservation of Coral Reefs

Climate change, pollution, overfishing, and habitat degradation are all major dangers to coral reefs, and global coral conservation projects are crucial in tackling these issues. These activities include international partnerships and research collaborations, as well as conservation programmes and restoration projects.

International Coral Reef Initiative (ICRI)

- **Overview:** The ICRI is a partnership among **governments, international organisations, and non-government organisations** that aims to preserve coral reefs and related ecosystems around the world. **Established in 1994,** the ICRI works to **raise awareness, share information and strategies,** and promote the implementation of effective coral reef management practices.
- **Actions:** The ICRI has developed frameworks like the **Framework for Action** which outlines strategies for coral conservation, and supports the **Global Coral Reef Monitoring Network (GCRMN)** to assess the condition of the world's coral reefs.

United Nations Environment Programme (UNEP)

- **Coral Reef Unit: UNEP's Coral Reef Unit** works to support the conservation and sustainable management of coral reefs and closely associated ecosystems. It collaborates with partners across the globe to implement projects and policies aimed at reef conservation.
- **Initiatives:** UNEP supports initiatives such as the **Green Fins,** which focuses on reducing the environmental impacts of the diving and snorkeling industry on coral reefs.

Global Coral Reef Monitoring Network (GCRMN)

- **Purpose:** The GCRMN's goal is to gather, **examine, and disseminate information on the state and trends of coral reef** health globally with the assistance of ICRI and other partners. This network plays a crucial role in providing the scientific basis for policy and management decisions regarding coral reefs.
- **Reports:** The GCRMN publishes regular reports on the status of coral reefs, which are vital for tracking changes over time and identifying threats.

Coral Triangle Initiative (CTI)

- **Region:** The **Coral Triangle,** located in the **Indo-Pacific,** is the most biodiverse marine region in the world. The CTI is a multilateral partnership of **six countries (Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands, and Timor-Leste)** aimed at protecting the Coral Triangle's marine and coastal resources.
- **Goals:** The CTI focuses on improving **marine protected area management, sustainable fisheries, and climate change adaptation measures.**

Reef Check Foundation

- **Mission:** The **Reef Check Foundation is a non-profit organisation** dedicated to conserving tropical coral reefs and **California rocky reefs** through education, research, and community involvement. It trains volunteers to conduct scientific surveys of reef health, contributing valuable data for reef management.
- **Programmes:** Reef Check's Eco Diver programme allows **recreational** divers to participate in coral reef monitoring and conservation efforts.

The Nature Conservancy's Global Coral Reef Conservation Programme

- **Approach: The Nature Conservancy (TNC)** works on protecting coral reefs through a variety of strategies, including establishing **marine protected areas, restoring damaged reefs, and implementing sustainable fisheries management practices.**
- **Innovations:** TNC has been involved in pioneering coral restoration techniques, such as coral gardening and **micro-fragmentation,** to accelerate the growth and recovery of coral reefs.

These global efforts are a concerted attempt to meet the critical need for coral reef protection. These programmes, which combine scientific study, policy lobbying, community involvement, and restoration projects, aim to preserve the long-term survival and resilience of coral reef ecosystems worldwide.

Conservation of Coral Reefs in India

Coral reef conservation in India requires a multi-dimensional approach that includes policies, initiatives, legal measures, and participation from various governmental and non-governmental organisations. These initiatives seek to maintain and restore key coral reef ecosystems throughout the Indian subcontinent.

Policies and Initiatives

- **National Coastal Management Programme (NCMP)** Aimed at promoting sustainable development and conservation of coastal ecosystems, including coral reefs.
- **Integrated Coastal Zone Management (ICZM) Project:** The **World Bank** is funding this project, which aims to improve coastal zone management procedures, including coral reef conservation, in states like **Gujarat, Odisha, and West Bengal.**

Legal Measures and Acts

- **The Environment (Protection) Act, 1986:** The act provides a framework for the protection and improvement of the environment, including coral reefs. It empowers the government to take measures necessary to protect and improve the environment.
- **Wildlife (Protection) Act, 1972:** It was amended to include coral reefs under its protection, prohibiting their harvesting, commercial exploitation, and trade without permission.
- **Coastal Regulation Zone (CRZ) Notification, 2011:** Revised in 2018, this notification under the **Environment Protection Act, 1986,** regulates activities in coastal areas to protect coastal ecosystems, including coral reefs.

Governmental Organisations

- **The Ministry of Environment, Forest and Climate Change (MoEF&CC):** MoEF&CC plays a pivotal role in formulating policies and programmes for coral reef conservation in India.
- **Zoological Survey of India (ZSI):** ZSI conducts research and surveys on the biodiversity of coral reefs, contributing to their conservation and management.
- **National Biodiversity Authority (NBA):** It works towards the conservation of biodiversity, including coral reefs, and ensures the sustainable use of its components.

Non-Governmental Organisations (NGOs)

- **Reef Watch Marine Conservation:** Works on marine conservation projects, including coral reef restoration, research, and education programmes.
- **Wildlife Trust of India (WTI):** WTI engages in various conservation projects, including efforts to protect marine biodiversity and coral reefs.
- **WWF-India:** It implements projects aimed at conserving marine life and habitats, including coral reefs, through community engagement, policy advocacy, and on-ground conservation actions.

Research and Monitoring

- **Global Coral Reef Monitoring Network (GCRMN):** India participates in this international network, contributing to global efforts in monitoring the health of coral reefs.
- **Coral Reef Monitoring Stations:** These stations have been established in key locations like the Gulf of Mannar and Lakshadweep to monitor reef health and assess the impacts of conservation measures.

Restoration Projects

- **Coral Gardening and Artificial Reefs:** Initiatives like coral gardening in the **Gulf of Kachchh** and the deployment of **artificial reefs in Lakshadweep** are aimed at rehabilitating degraded reef areas.

These concerted efforts reflect India's commitment to preserving its coral reef ecosystems, which are crucial for biodiversity, coastal protection, and supporting the livelihoods of coastal communities.

Biorock Technology

- **About**
  - Biorock technology, also known as Mineral Accretion Technology or Seament, was invented in 1976 by architect Professor Wolf Hilbertz.
  - It represents a groundbreaking approach to producing natural building materials in the sea, characterized by materials that grow over time, increase in strength, and have the capacity for self-repair.
- **Applications and Benefits**
  - Biorock technology has found applications beyond building materials, extending to fish and shellfish mariculture and the construction of limestone breakwaters to protect against coastal erosion and sea-level rise.
  - Powered by renewable energy sources, Biorock offers a sustainable solution to marine habitat restoration, demonstrating significant benefits in accelerating coral recovery and enhancing marine biodiversity.
- **Global Implementation and Impact**
  - With around 500 reef structures built in approximately 40 countries.
  - These structures have proven effective in restoring marine ecosystems, offering a cost-effective and rapid solution to marine conservation challenges.

Way Forward for the Conservation of the Coral Reefs

Coral reef conservation is vital because of its ecological value, support for biodiversity, and countless advantages to human societies. Effective conservation efforts require a multifaceted strategy that includes policy, science, and community engagement. Here are crucial steps that must be performed to conserve corals:

- **Reducing Greenhouse Gas Emissions: Global Action:** Addressing the root cause of global warming by **reducing greenhouse gas** emissions is crucial. This involves transitioning to renewable energy sources, improving energy efficiency, and adopting sustainable land use practices.
- **Implementing Sustainable Fishing Practices: Regulation and Enforcement: Overfishing and destructive fishing** practices harm coral ecosystems. Implementing and enforcing **sustainable fishing regulations** can help maintain balanced marine populations and support reef health.
- **Managing Tourism Sustainably: Eco-friendly Practices:** Tourism can contribute to coral damage. Promoting eco-friendly tourism practices, such as **responsible snorkelling and diving,** and educating tourists about reef conservation can minimise human impact.
- **Controlling Pollution: Waste Management:** Reducing pollution from **land-based sources** by improving waste management, controlling agricultural runoff, and treating sewage before it reaches the ocean can significantly reduce stress on coral reefs.
- **Restoring Damaged Reefs: Coral Restoration Projects:** Techniques such as coral gardening, transplantation, and the use of artificial reefs can help restore degraded coral ecosystems. These projects often involve growing corals in nurseries before transplanting them back to damaged areas.
- **Protecting Coral Habitats: Marine Protected Areas (MPAs):** Establishing and effectively managing MPAs can protect coral reefs from human activities, allowing ecosystems to recover and thrive.

Governments, non-governmental organisations (NGOs), scientists, local communities, and international agencies must all work together to put these steps into action. Coral reef conservation is about more than just preserving biodiversity; it is also about supporting the livelihoods of millions of people who rely on these ecosystems for food, money, and protection from storms and erosion.

CONCLUSION

Wetlands, mangroves, and coral reefs are critical to the planet's **biological and environmental health**, that provide unmatched benefits ranging from biodiversity support to climate regulation and coastal protection. Their position as natural cleaners, defenders, and nurseries emphasises the critical need for coordinated global conservation efforts. As these critical ecosystems confront rising challenges from **human activity and climate change,** protecting their integrity is not only an environmental imperative, but also a requirement for the survival of human civilization. Wetlands, mangroves, and coral reefs must be protected and restored to ensure that future generations inherit a resilient and biodiverse planet.

Biodiversity

5

INTRODUCTION

India's great biodiversity reflects the country's **distinct geographical, climatic and ecological diversity.** India is home to an incredible diversity of flora and wildlife, ranging from the frigid heights of the Himalayas to the lush greenery of the Western Ghats, the parched deserts of Rajasthan, and the brilliant coral reefs of the Andaman and Nicobar Islands. This biodiversity **not only serves as a source of national pride, but it also supports the country's ecological stability,** economic prosperity and cultural heritage. However, these natural riches are under threat from a variety of sources, including habitat degradation, pollution, climate change, overexploitation, and invasive species. The conservation of India's biodiversity is thus a critical issue that necessitates collaborative efforts at the local, national and global level.

THE FUNDAMENTALS OF BIODIVERSITY

- **Biodiversity** refers to the vast variety of life found in a particular area, encompassing **animals, plants, fungi, and microorganisms** like bacteria that constitute our natural world.
- These diverse forms of life interact within ecosystems, forming a complex web that maintains balance and supports life.
- Biodiversity is crucial for providing essential resources for survival, including food, clean water, medicine, and shelter.
- **Approximately 1.2 million species** have received formal descriptions. **Animals constitute over 70% of all recorded species,** while plants, including algae, fungi, bryophytes, gymnosperms, and angiosperms, make up about 22%. In the animal kingdom, **insects** represent the most species-rich taxonomic group, accounting for over 70% of the total.
- However, human activities are putting biodiversity at risk by consuming resources at an unsustainable rate, leading to a significant imbalance in ecosystems.

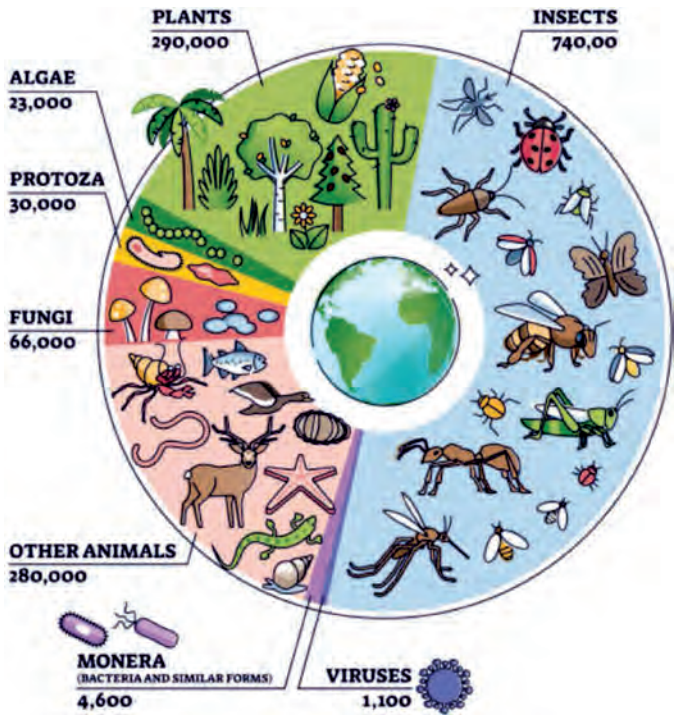


Fig. 5.1: Biodiversity on Earth

- This has resulted in a dramatic decline in global populations of various species, with an **average 69% drop in mammals, fish, birds, reptiles, and amphibians since 1970.**
- Moreover, about **1 million animal and plant species** are now threatened with extinction, marking the highest number in human history.
- Human actions such as **overfishing, deforestation, pollution,** and contribution towards climate change are severely impacting biodiversity across the globe.

TYPES AND LEVELS OF BIODIVERSITY

Biodiversity is all the different kinds of life you'll find in one area—the variety of animals, plants, fungi, and even microorganisms like bacteria that make up our natural world. Each of these species and organisms work together in ecosystems, like an intricate web, contributing towards habitat complexity and resilience to maintain balance and support life. Biodiversity is roughly grouped into three categories: **genetic diversity, species diversity, and ecological diversity.** The following are the types of Biodiversity:

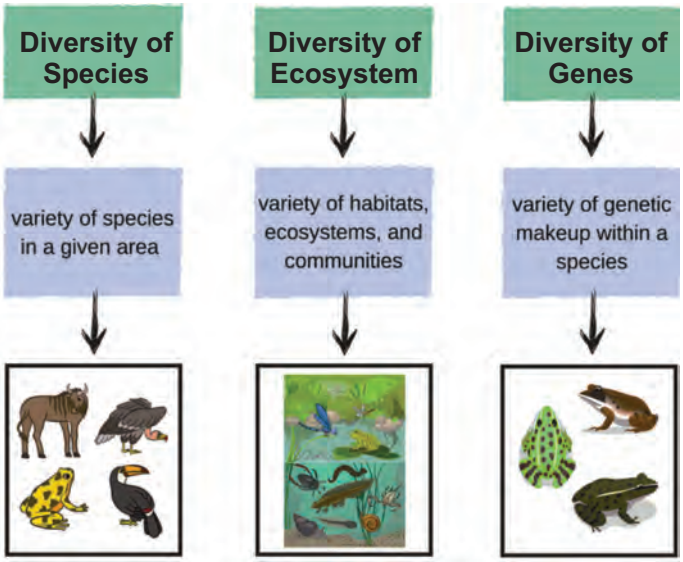

Diversity of Species
Diversity of Ecosystem
Diversity of Genes
variety of species in a given area
variety of habitats, ecosystems, and communities
variety of genetic makeup within a species

Fig. 5.2: Types of Biodiversity

Genetic Diversity

- Genetic diversity refers to the **variation in genes within a species.** This diversity is seen in the different genetic compositions that individuals of a species possess, which can lead to variations in **appearance, behaviour and resilience** to diseases and environmental changes.
- For instance, **kangaroos** have **low genetic diversity** due to their recent evolutionary lineage, compared to **dasyurids-** family of marsupials (such as the Tasmanian Devil, the Numbat and quolls), which are **genetically more diverse** due to their ancient lineage.
- Conserving genetic diversity is crucial because it ensures species adaptability and survival under changing environmental conditions.

Species Diversity

- Species diversity is about the variety of species within a habitat or region. This diversity can vary significantly from one habitat to another, with some areas like **rainforests and coral reefs being rich in species,** while others, such as salt flats or polluted streams, may have fewer species.
- Australia is highlighted for its **high rate of endemism,** with more than **80%** of its plant and animal species being unique to the continent.
- This includes entire families of mammals, birds and flowering plants that are found nowhere else on Earth.
- The diversity of species is fundamental for the functioning of ecosystems, providing a range of ecological services from pollination to nutrient recycling.

Measurement of Species Diversity

- **Species diversity** is a measure of the **variety of species within an ecosystem** and is composed of two components: **species richness and species evenness.**
  - **Species richness:** This is the count of different species present in an ecosystem. Ecosystems with high species richness are often more resilient and productive because they contain a wide array of species that can perform various ecological roles.
    - **Example:** In a **tropical** rainforest, there might be a vast number of different species occupying various niches within the ecosystem, leading to high species richness. However, due to factors such as competition for resources, predation, and environmental conditions, the abundance of each species may vary significantly. This variation can result in low species evenness.
  - **Species Evenness:** This aspect measures **how evenly the individuals of different species** are distributed within an ecosystem. High evenness indicates that no single species dominate the ecosystem, promoting a balanced and healthy environment.
    - In a forest, there may be only a few plant species (low species richness) but a large number of each species (high species evenness).
    - **Example -Boreal forests,** are limited to species that can tolerate the extreme cold. The most common species are deciduous trees and evergreen conifers like pine, fir, and spruce.
- Species diversity, a crucial term in ecology, is seen at three different scales, like **alpha, beta, and gamma diversity,** each providing unique insights into the ecological complexity of landscapes.

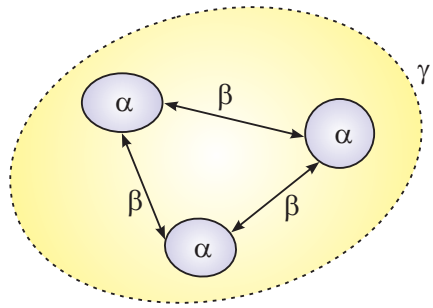


Fig. 5.3: Scales of Species Diversity

- **Alpha Diversity:** Alpha diversity refers to the **species diversity within a single ecosystem or community at a local scale.** It is the diversity most people refer to while discussing the variety of species in a specific area. This level of diversity focuses on the **number and abundance of species in individual habitats or ecosystems.**
- **Beta Diversity:** Beta diversity **examines the species diversity between two different communities or ecosystems,** often separated by geographical barriers like rivers or mountain ridges. It measures the change in species composition from one ecosystem to another, providing insights into ecological differentiation across landscapes.

- **Gamma Diversity:** Gamma diversity is considered at a **much larger scale,** such as a **biome,** and represents the overall species diversity across multiple ecosystems within a larger area. This could encompass, for example, the entire range of a mountain slope or a coastal zone, integrating the species diversity of all the individual ecosystems within the area.

❑ **Importance of Alpha, Beta and Gamma Diversity**

- Understanding these three levels of diversity is crucial for biodiversity conservation, especially in the face of **habitat fragmentation and climate change.**
- Each level of diversity plays a role in the resilience and health of ecosystems. For instance, habitat fragmentation can reduce alpha diversity within patches and alter beta diversity between them, potentially leading to a decrease in overall gamma diversity.

❑ **Simpson's Index**

- The Simpson's Index is a measure used to **quantify the biodiversity of a habitat.**
- It takes into account both the number of species present (species richness) and the dominance or abundance of each species (species evenness).
- A high Simpson's index indicates a **diverse ecosystem** with a balanced distribution of species, while a low index suggests a less diverse ecosystem or one dominated by a few species.

❑ **Shannon-Wiener Index**

- Shannon-Wiener Index is a measure of biodiversity, that quantifies the species richness and evenness within a community or ecosystem.
- It considers **both the number of species present and their relative abundance,** providing a comprehensive assessment of biodiversity.
- **India State of the Forest report** incorporates the Shannon-Wiener Index, providing insights into the species richness and diversity of various forest types across states and union territories, along with relative species abundance data.

IGNITE YOUR MIND

The Symphony of Life:

Can you imagine a silent world? Dive into the fascinating concept of biodiversity and its crucial role in maintaining a healthy planet for ourselves and future generations. Why is losing biodiversity like losing the instruments in a symphony?

Ecosystem Diversity

❑ **Ecosystem diversity** refers to the variety of ecosystems within a certain area. An ecosystem comprises a community of living organisms and their **physical environment,** interacting as a system.

❑ These ecosystems can range in size from **large forests to small ponds** and include diverse habitats like the **Great Barrier Reef** or the unique ecosystem on the back of a spider crab.

❑ The diversity of ecosystems is vital for supporting a wide range of life forms and ecological processes that sustain life on Earth.

❑ A region with several ecosystems may be able to provide more resources to help native species survive, especially when one ecosystem is threatened by drought or disease.

Understanding the various types of biodiversity and their components is critical for conservation efforts because it helps identify the regions of greatest need and the most effective tactics for preserving the natural world's complicated balance.

Rivet Popper Hypothesis

❑ Paul Ehrlich proposed the Rivet Popper Hypothesis, **emphasizing the crucial role of species richness in ecosystem stability.**

❑ The hypothesis draws an analogy between the rivets holding together an airplane's structure and the species within an ecosystem. Just as removing rivets weakens an airplane's integrity, reducing species diversity can undermine the resilience and functionality of an ecosystem.

Trophic Cascade

❑ **A trophic cascade refers** to a chain reaction across a food web, initiated by a population change at one trophic level, which influences both higher and lower levels in the hierarchy.

❑ Removal of a keystone species can trigger trophic cascades, where changes in one trophic level cascade through the entire food web.

❑ For example, the loss of a top predator can lead to an increase in prey species, which may then overexploit lower trophic levels, causing imbalance.

PATTERNS OF BIODIVERSITY

❑ Biodiversity patterns refer to the **distribution and diversity of species throughout different parts** of the Earth, which vary depending on **geography, temperature, and time.**

❑ These patterns are critical for understanding the complexities of life and the interactions between organisms and their surroundings.

Global Variation

- **Climate:** The climate of a region plays a crucial role in shaping its biodiversity. **Tropical climates,** with their **warm temperatures and high rainfall,** support lush rainforests teeming with life. In contrast, **polar regions, characterised by cold temperatures,** support fewer species, which are highly adapted to survive in harsh conditions.
- **Geographical Isolation:** Islands and remote areas often harbour unique species that have evolved in isolation. **The Galápagos Islands**, for example, are home to species found nowhere else, such as **marine iguanas** and the famous **Galápagos tortoises**, which have adapted to the island's specific environmental conditions.
- **Habitat Diversity:** Regions with a variety of habitats, such as mountains, forests, rivers, and lakes, tend to have higher biodiversity. The varied landscapes of the Himalayas, ranging from tropical forests at lower elevations to alpine meadows and glaciers at higher altitudes, support a wide array of species adapted to different niches.
- **Historical Factors:** The history of a region, including geological events like **volcanic eruptions, mountain formations, and continental drift,** as well as historical climate changes, has shaped the distribution and evolution of species. The separation of continents has led to the development of distinct flora and fauna in different parts of the world.
- Convergent Evolution
  - **Convergent evolution** illustrates how species from **different lineages can develop similar traits** in response to analogous environmental challenges. This phenomenon is evident not only in the flightless birds mentioned earlier but also in other species:
  - **Cacti and Euphorbias:** In the deserts of North America, cacti have evolved thick, water-storing stems and spines for water conservation and protection. Similarly, in the arid regions of Africa, euphorbias have independently evolved comparable adaptations, despite being unrelated to cacti.
  - **Aquatic Mammals:** Dolphins (marine mammals) and ichthyosaurs (extinct marine reptiles) exhibit remarkable similarities in body shape, adapted for efficient swimming in aquatic environments. These adaptations include streamlined bodies, dorsal fins and flippers, despite their vastly different evolutionary histories.

Local Variation

- **Microclimate Variations:** Even within a single geographic region, **variations in sunlight, moisture, elevation, and soil types** can create a **mosaic of microclimates,** each supporting different species. For example, the north side and south side of a mountain may support vastly different plant and animal communities due to differences in sunlight exposure and moisture.
- **Habitat Diversity:** The presence of diverse habitats, such as **rivers, lakes, forests, and meadows,** within a close range can support a wide range of species adapted to each habitat type. This diversity within a localised area contributes to the overall biodiversity of the region.
- **Isolation: Geographic or ecological barriers** within a region can lead to the isolation of species populations, promoting divergent evolution and the development of unique species or subspecies. This is often seen on **islands or in "habitat islands"** within larger landscapes, such as isolated springs in deserts.
- **Example:** The **Galapagos Islands** serve as a prime example, where even closely situated islands have unique climatic conditions leading to variations in species, such as the tortoises with different shell shapes adapted to their specific island's environment.

Temporal Variation

- Over time, species undergo changes, leading to **temporal variations** in biodiversity.
- Fossil records show that prehistoric animals often resemble modern species, indicating how species evolve over geological timescales.
- Temporal variation in biodiversity underscores the dynamic and ever-changing nature of life on Earth. This variation manifests through several distinct but interconnected processes, including seasonal changes, ecological succession, and long-term evolutionary shifts. Each of these processes contributes to the rich tapestry of life, demonstrating the adaptability and resilience of species over time.
- **Seasonal Variation:** Seasonal variation reflects the **changes in biodiversity in response to the cyclical patterns of the Earth's climate.** These changes can significantly affect the behaviour, distribution, and life cycles of species.
  - **Example:** The monarch butterfly's migration is a remarkable example of adaptation to seasonal changes. Each year, monarchs travel thousands of miles from North America to the warmer climates of central Mexico for the winter, returning north in the spring. This migration is not only a response to changing temperatures, but also ensures access to breeding habitats and food resources.
- **Successional Variation:** Successional variation occurs as ecosystems undergo a **series of stages in response to disturbances,** leading to changes in the species composition over time. This process, known as ecological succession, can be observed in both terrestrial and aquatic environments.
  - **Example:** The transformation of a landscape following a volcanic eruption exemplifies ecological succession. Initially barren, the area is gradually colonised by pioneer species such as lichens and mosses, followed by grasses, shrubs, and eventually, trees, leading to the reestablishment of a complex forest ecosystem over centuries.

- **Evolutionary Variation:** Evolutionary variation encompasses the **long-term changes in species and ecosystems due to genetic mutations, natural selection, and other evolutionary forces**. Fossil records provide crucial insights into these changes, revealing the ancestors of modern species and their adaptations over geological timescales.
  - **Example:** The evolution of cetaceans from land-dwelling mammals to the aquatic whales and dolphins present today, is a profound illustration of evolutionary adaptation. Fossil records show a gradual transition in body shape, limb structure and sensory organs, highlighting the dramatic transformations these species have undergone to thrive in marine environments.

Latitudinal and Altitudinal Variation

- **Latitude, Altitude and the size of the habitats** all have an impact on the remarkable variation in biodiversity that occurs across different geographical regions. This variation is crucial for understanding the distribution of life on Earth and the ecological processes that sustain it. Tropical regions near the equator have **higher biodiversity** than temperate and polar zones, attributed to more **favourable climatic conditions** for life. This gradient shows a **decrease** in species richness and diversity **from the equator towards the poles.**

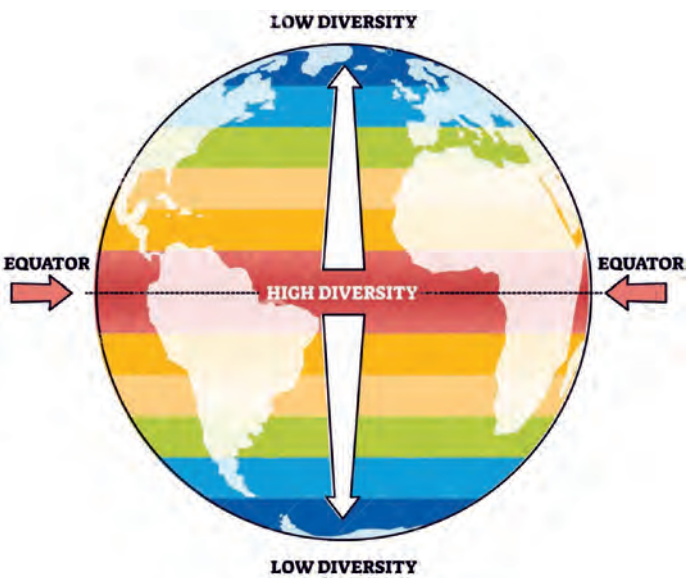


Fig. 5.4: Latitudinal Diversity Gradient

- **Latitudinal Gradient:** The latitudinal gradient in biodiversity is a well-documented pattern where **regions closer to the equator exhibit higher biodiversity than those near the poles.** This gradient is attributed to the more favourable climatic conditions for life in the tropics, including warmer temperatures and higher levels of precipitation.
  - **Tropical Regions:** These areas are characterised by **warm temperatures year-round and significant rainfall,** leading to lush, diverse ecosystems such as rainforests. **The Amazon Rainforest,** for example, is one of the most biodiverse places on Earth, home to **over 3 million species of animals, plants, and insects.** The richness here is not just in the number of species but also in the ecological roles they play.
  - **Temperate Regions:** Situated between the **tropics and the polar circles,** these regions experience more seasonal variation in climate. Temperate forests, grasslands, and deserts host a moderate level of biodiversity. **The Great Smoky Mountains in the United States,** for example, are known for their diversity of plant life, with over **1,500 flowering plant species.**
  - **Polar Regions:** The biodiversity in polar regions such as the **Arctic and Antarctic** is lower compared to tropical and temperate regions, primarily due to the extreme cold and the scarcity of liquid water. However, these regions still support unique species adapted to cold environments, such as polar bears in the Arctic and penguins in the Antarctic.
- **Species-Area Relationships:** The diversity of species increases with the area under observation. This relationship, first observed by **Alexander Von Humboldt,** suggests that larger areas tend to support more species due to a greater variety of habitats and ecological niches. The species-area relationship is mathematically represented as **Log S = log C + Zlog A,** where S is species richness, C is a constant, A is the area, and Z is the slope of the line or the regression coefficient.
- **Impact of Altitude on Biodiversity Patterns**
  - Altitude also significantly impacts **biodiversity patterns.** As **altitude increases, the climate becomes cooler and harsher,** which affects the types of species that can survive.
  - **Low Altitude:** At lower altitudes, conditions are **generally warmer and more hospitable,** supporting rich biodiversity similar to that found in nearby latitudinal zones. For instance, the foothills of the Himalayas are covered in dense subtropical forests.
  - **Mid-Altitude:** Mid-altitude regions often feature mixed forests or montane grasslands, with species compositions that change gradually with increasing elevation. The **Monteverde Cloud Forest in Costa Rica** is an example, known for its high biodiversity, including over **2,500 plant species** and hundreds of species of birds.
  - **High Altitude:** High-altitude environments, such as **alpine tundras and glaciers,** support fewer species due to extreme conditions. However, these areas harbour unique species adapted to cold and low oxygen levels, such as the snow leopard in the Himalayas.

IGNITE YOUR MIND

Beyond Names and Numbers:

Biodiversity isn't just about counting different species like collecting Pokemon! It's about understanding the hidden layers, from the unique code within every creature to the diverse ecosystems that work together like a giant puzzle. How do these different levels create a thriving web of life?

CLASSIFICATION OF LIFE ON EARTH

The diversity of life on Earth is astonishing, with millions of species inhabiting our planet, from the deepest oceans to the highest mountains.

- To understand and study this vast array of life forms, scientists have developed a hierarchical classification system. **Carl Linnaeus** developed this system in the **18th** century to classify living things into groups based on shared traits.
- The classification encompasses several levels, starting from the broadest category, the kingdom and narrowing down to the most specific, the species.
- Here, we present an overview of the classification of the plant and animal kingdoms, illustrating the structure of biological taxonomy with examples at each hierarchical level.
- The hierarchy of plant kingdoms is as follows: **kingdom phylum (division), class, order, family, genera, and species**.
- Whereas the hierarchy of an animal kingdom is as follows: **Kingdom, phylum, class, order, family, genera, and species**.

Plant Kingdom

The plant kingdom is traditionally divided into two main groups: **Cryptogamae and Phanerogamae.** Cryptogamae, or non-flowering plants, are characterised by the absence of visible flowers and seeds, reproducing instead through spores. Phanerogamae, or flowering plants are known for their visible reproductive structures, which produce flowers and seeds.

- **Cryptogamae** is further divided into three sub-types:
  - **Thallophyta:** These are the most primitive plants, consisting of **algae, fungi, and lichens.** Thallophytes have a simple body structure **without a distinct stem, root, or leaf,** often referred to as a thallus.
  - **Bryophytes:** This group includes **mosses, liverworts and hornworts.** Bryophytes are non-vascular, meaning they lack the xylem and phloem found in other plants, and they thrive in moist environments.
  - **Pteridophytes:** Comprising **ferns, horsetails, and club mosses,** pteridophytes are vascular plants that reproduce via spores. They have a more complex structure than bryophytes, with distinct roots, stems, and leaves.
- **Phanerogamae** is divided into two major groups:
  - **Gymnosperms:** These are **seed-producing plants,** such as **conifers,** where the seeds are not enclosed in an ovary but are often found on the scales of a cone.
  - **Angiosperms:** The largest group in the plant kingdom, **angiosperms produce flowers and seeds enclosed within a fruit.** They are further classified into **monocots and dicots,** based on the number of cotyledons in the seed.

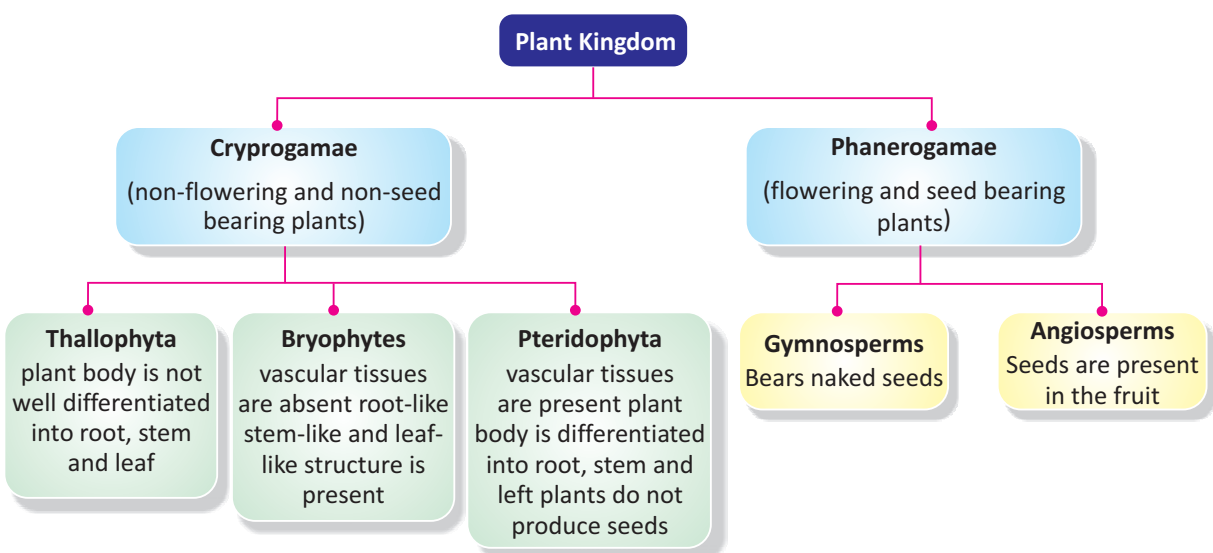

Plant Kingdom
Cryprogamae
(non-flowering and non-seed bearing plants)
Phanerogamae
(flowering and seed bearing plants)
Thallophyta
plant body is not well differentiated into root, stem and leaf
Bryophytes
vascular tissues are absent root-like stem-like and leaf-like structure is present
Pteridophyta
vascular tissues are present plant body is differentiated into root, stem and left plants do not produce seeds
Gymnosperms
Bears naked seeds
Angiosperms
Seeds are present in the fruit

Fig. 5.5: Plant Kingdom

The division of the plant world into Cryptogamae and Phanerogamae, together with their respective subtypes, gives an organised approach to understanding the diversity and complexity of plant life on Earth. From basic, non-vascular thallophytes to complicated, seed-producing angiosperms, each category is critical to our planet's ecosystems. This summary is based on accepted botanical classifications and concepts discovered in scientific literature and credible educational resources.

Animal Kingdom

The **animal kingdom** is broadly classified into two sub-kingdoms based on the complexity of their cellular organisation and body plan: **Parazoa and Eumetazoa** (often referred to as Metazoa in broader classifications). This division helps in understanding the evolutionary lineage and the diversity of life forms within the animal kingdom.

❑ Sub-Kingdom Parazoa

- Parazoa consists of animals that **lack true tissues and organs** and have a relatively **simple body structure.** The most notable group within Parazoa is:
- **Porifera (Sponges)**
  - ❒ These are the simplest forms of **multicellular animals.** Porifera are characterised by their porous bodies and a unique feeding system.
  - ❒ They live attached to solid surfaces in **marine and freshwater environments.**
  - ❒ Sponges have a body plan that includes an outer layer of cells and an inner layer separated by a gelatinous substance called **mesohyl,** but they lack true tissues and organs.

❑ Sub-kingdom Metazoa

- The sub-kingdom Metazoa, which encompasses **all multicellular animals** with organised tissues, can be further divided into two major groups based on the **presence or absence of a notochord,** a flexible rod-like structure that plays a crucial role in the development of the nervous system. These two groups are Non-Chordata and Chordata.
- **Non-Chordata:** Non-Chordates are animals that **do not develop a notochord at any stage** of their life cycle. This group includes a vast array of animals, each belonging to different phyla based on their unique characteristics. Some of the major phyla under Non-Chordata include:
  - ❒ **Porifera:** Sponges, simple animals with porous bodies.
  - ❒ **Cnidaria:** Jellyfish, corals, and sea anemones, known for their stinging cells.
  - ❒ **Platyhelminthes:** Flatworms, including tapeworms and liver flukes.
  - ❒ **Nematoda:** Roundworms, which are cylindrical and unsegmented.
  - ❒ **Annelida:** Segmented worms like earthworms and leeches.
  - ❒ **Mollusca:** A diverse group including snails, clams, and squids.
  - ❒ **Arthropoda:** The largest phylum, including insects, spiders, and crustaceans.
  - ❒ **Echinodermata:** Marine animals like starfish, sea urchins and sea cucumbers.
- **Chordata:** Chordates are animals that, at some stage in their life cycle, possess a notochord, a dorsal nerve cord, pharyngeal slits, and a post-anal tail. Chordata is divided into three subphyla:
  - ❒ **Urochordata (Tunicata):** Sea squirts and salps, where the notochord is present only in the larval stage.
  - ❒ **Cephalochordata (Acrania):** Lancelets, small marine animals with a notochord extending the length of their body.
  - ❒ **Vertebrata:** Animals with a backbone or spinal column. Vertebrates are further classified into several classes, including:
    - ◊ **Fish (Pisces):** Aquatic, gill-breathing vertebrates that usually have fins and scales.
    - ◊ **Amphibians:** Vertebrates that live both in water (as larvae) and on land (as adults), such as frogs and salamanders.
    - ◊ **Reptiles:** Cold-blooded vertebrates with scales, such as snakes, lizards, and turtles.
    - ◊ **Birds (Aves):** Warm-blooded vertebrates with feathers and wings.
    - ◊ **Mammals:** Warm-blooded vertebrates with hair or fur; females possess mammary glands to feed their young.

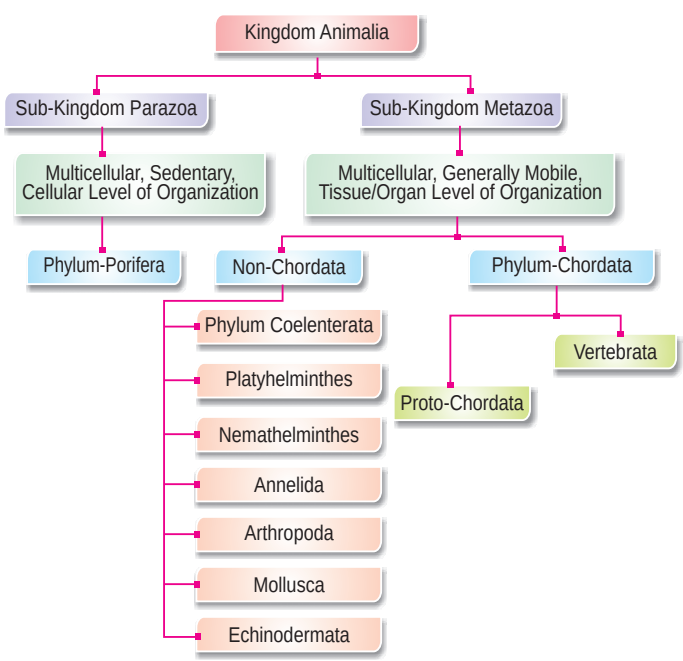


Fig. 5.6: Kingdom Animalia

The hierarchical classification method helps biologists to categorise and comprehend the relationships between various kinds of life. Scientists can better communicate about life's diversity and evolutionary history by categorising species into kingdoms, phyla, classes, orders, families, genera, and species. This approach emphasises the interconnectivity of all living organisms, from the smallest bacterium to the greatest mammals, as well as the need for biodiversity conservation for our planet's health. The examples for the Plant and Animal Kingdoms provide a glimpse into this enormous and complicated web of life, exhibiting nature's beauty and complexity.

FUNCTIONS OF BIODIVERSITY

Biodiversity, or biological diversity, refers to the variety and variability of life on Earth. It comprises diversity within species, between species, and across ecosystems. The purposes of biodiversity are numerous and essential to the survival of living organisms, including humans.

Ecosystem Services

- Biodiversity provides a range of **ecosystem services** that are essential for human survival and economic activity.
- These services are often categorised into provisioning services (such as food, fibre, and medicine), regulating services (such as climate regulation, flood control, heatwaves, and disease regulation), supporting services (such as soil formation and nutrient cycling), and cultural services (such as recreational, spiritual, and educational benefits).
- **Example: Mangroves,** which are diverse coastal ecosystems, provide critical storm protection, fishery support, and carbon sequestration services.

Nutrient Cycling

- Biodiversity plays a crucial role in **nutrient cycling**, ensuring the sustainability of ecosystems by recycling nutrients essential for plant and animal life.
- **Example:** In the **Amazon Rainforest,** the diversity of decomposers helps break down dead plant and animal matter, returning nutrients to the soil for use by living plants.

Pollination

- Many plants depend on animals for pollination, which is essential for the production of **fruits, vegetables and seeds.**
- Bees, butterflies, birds and bats are just a few of the animals that primarily provide this service.
- **Example:** Bees, which are a part of biodiversity, are responsible for pollinating **approximately 75% of the crops used by humans for food worldwide.**

Genetic Resources

- Biodiversity is a source of **genetic material** that is vital for breeding programmes in agriculture, medicine and biotechnology.
- This genetic diversity helps in developing new crops and medicines, enhancing food security, and providing raw materials for industry.
- **Example:** The discovery of the gene responsible for **drought tolerance** in wild maize has been used to develop drought-resistant maize varieties.

Climate Regulation

- Biodiversity contributes to climate regulation through **carbon sequestration** and influences local and global climates.
- Forests, oceans, and wetlands play key roles in carbon storage and regulating the Earth's climate.
- **Example:** The Amazon Rainforest, often referred to as the **"lungs of the Earth,"** absorbs large amounts of CO_2, helping to mitigate climate change.

Water Regulation and Purification

- Biodiversity contributes to water quality by **filtering pollutants and regulating water flow,** thus preventing floods and purifying water.
- **Example: Wetlands** act as natural water purifiers by trapping pollutants and sediments from the water that flows through them.

Cultural and Recreational Value

- Biodiversity enriches cultures and provides **recreational opportunities.** Many societies attach spiritual and religious values to certain species and natural sites.
- **Example: National parks and wildlife reserves** not only protect biodiversity but also offer recreational and educational opportunities for people.

Conservation of Biodiversity and Forestry

- **Sustainable Forest Management (SFM):** SFM is a core principle for mainstreaming biodiversity, emphasising the **conservation and sustainable** use of forest resources to meet current needs without compromising the ability of future generations to meet theirs.
- **Integrated Land Use Planning:** This involves considering biodiversity conservation in the broader context of land use planning, ensuring that forest management practices are **harmonised with other land uses** to maintain ecological integrity and connectivity.
- **Protected Areas and Conservation Measures:** Establishing protected areas within **forest landscapes and implementing specific conservation** measures for threatened species and habitats are crucial for preserving biodiversity.

- **Climate Change Mitigation and Adaptation:** Forests play a key role in mitigating climate change by **sequestering carbon dioxide.** Mainstreaming biodiversity in forestry also involves adapting management practices to the impacts of climate change, ensuring the resilience of forest ecosystems and the biodiversity they support.
- **Community Involvement and Traditional Knowledge:** Engaging local communities and indigenous peoples in forest management, and recognising their traditional knowledge and practices can enhance **biodiversity conservation and the sustainable use of forest resources.**
- **Monitoring and Research:** Continuous monitoring of biodiversity within forest ecosystems and research on the impacts of different management practices are essential for informed decision-making and adaptive management.

Assisted Natural Regeneration (ANR)

- **Assisted natural regeneration** is a combination of **active planting and passive restoration** in which locals intervene to help trees and native flora regenerate naturally by removing barriers and dangers to growth, relying on their knowledge of the area and ancient traditions.
- It focuses on protecting and nurturing the natural regrowth of forests in **degraded or deforested lands,** rather than planting new trees.
- This method is considered cost-effective, efficient, and sustainable for restoring forest ecosystems.
- **Benefits of ANR**
  - **Cost-Effectiveness:** ANR is generally more affordable than active tree planting because it leverages the existing seed bank and natural regenerative processes.
  - **Enhanced Biodiversity:** By allowing forests to regenerate naturally, ANR supports the restoration of native flora and fauna, enhancing biodiversity.
  - **Improved Ecosystem Services:** Naturally regenerated forests are better at providing ecosystem services such as carbon sequestration, water regulation, and soil stabilisation.
  - **Community Engagement:** ANR often involves local communities in the protection and monitoring of regenerating areas, fostering a sense of ownership and stewardship.
  - **Resilience to Climate Change:** Forests restored through ANR tend to be more resilient to climate change and other environmental stress

The patterns of biodiversity, which range from equatorial rainforests to frigid tundras, demonstrate the rich diversity of life on Earth. These patterns, which are influenced by elements such as latitude and altitude, emphasise the importance of ecosystems and their responsibilities in delivering critical services for human life. Understanding and protecting biodiversity is critical to ecosystem health and resilience. Conservation activities, such as Assisted Natural Regeneration (ANR), are critical to preserving these patterns for future generations, emphasising our commitment to long-term environmental care.

IGNITE YOUR MIND

Real-World Superpowers of Biodiversity:

Forget superheroes! Biodiversity holds the key to real-world superpowers, from medicines discovered in nature to the clean air we breathe and the food we eat. Explore the ways this hidden power benefits us every day.

BIOGEOGRAPHY

Biogeography is the study of the distribution of species and ecosystems across geographic space and geological time. It seeks to understand the factors that influence the distribution of organisms, such as climate, geography, and evolutionary history.

- The distribution of species and ecosystems on Earth is not random, but is influenced by a wide range of **environmental and historical factors.**
- Understanding these factors is critical for biogeography, which studies the distribution of biological diversity across space and time.
- In this section, we will look at some of the primary factors that influence biogeographical distribution:

Factors Influencing Bio-geographical Distribution

Climate (Temperature and Precipitation)

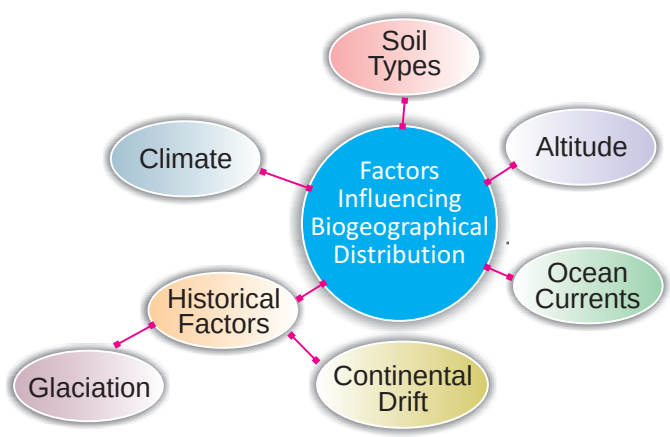


Fig. 5.7: Factors Influencing Bio-geographical Distribution

- **Climate** is arguably the most important factor influencing the distribution of life on Earth.
- **Temperature and precipitation** have a **direct impact** on the types of vegetation and animals that can thrive in a given area.
- **Tropical rainforests,** for example, have **high temperatures and rainfall,** allowing for a diverse range of plant and animal species to thrive.
- **Deserts,** on the other hand, receive **little precipitation** and can be extremely hot, allowing species to thrive in drier and sometimes hotter conditions.
- Climate affects not only the presence of specific species, but also the **productivity of ecosystems.**
- **Example: The Amazon Rainforest** is characterised by high temperatures and abundant rainfall year-round, creating conditions for a diverse range of species, including thousands of plants, birds, butterflies, and mammals, to thrive.

Altitude

- Altitude has a significant impact on **species distribution, primarily through climate.** As **altitude rises, the temperature drops,** causing changes in vegetation and wildlife.
- High-altitude environments, such as mountain ranges, can support ecosystems that differ significantly from those found at sea level.
- For example, the **flora and fauna** of the alpine regions differ from those of the adjacent lowland areas, with many exhibiting unique adaptations to colder temperatures and lower oxygen levels.
- **Example: The Andes Mountains in South America** exhibit a range of ecosystems, from tropical rainforests at their base to alpine tundra and glaciers at their highest elevations, each with unique species adapted to the conditions found at different altitudes.

Soil Types

- Soil types play an important role in determining which plants can grow in a given area, which influences the **animal species** that can inhabit it.
- Plants have different **nutrient requirements and tolerances** to **soil pH, moisture, and texture.**
- For example, **calcareous soils** support a different range of plant species than acidic soils, resulting in distinct biological communities.
- **Parent rock material, climate, topography, and biological activity** are a few factors that affect soil type distribution.
- **Example: The Serengeti Plains in Africa** are known for their nutrient-rich volcanic soils, which support vast grasslands. These grasslands, in turn, support large herds of herbivores like wildebeest and zebras, which are prey for predators such as lions and hyenas.

Ocean Currents

- Ocean currents have a significant impact on the climate and, thus, the **biological distribution** of coastal areas and islands.
- **Warm currents** can **increase temperatures and precipitation** along coastlines, promoting lush vegetation, whereas cold currents can cause drier and cooler conditions, limiting the types of species that can survive.
- Ocean currents also have an impact on marine biogeography by **distributing nutrients and influencing** water temperature, both of which affect marine ecosystems and the distribution of fish and other marine life.
- **Example: The convergence of several ocean currents, such as the warm El Nino current and the cold Humboldt current, has an impact on the Galápagos Islands.** This mix of currents contributes to the islands' unique climate and rich biodiversity, including marine iguanas and the Galápagos tortoise.

Historical Factors (Continental Drift, Glaciation)

- The movement of continents (continental drift), as well as **glaciation and deglaciation cycles,** have had a profound impact on the distribution of life on Earth.
- **Continental drift** has resulted in the separation and collision of landmasses, isolating populations and allowing for evolutionary diversity.
- This process has resulted in distinct flora and fauna across continents. **Glaciation cycles** have expanded and contracted habitats, forcing species to migrate, adapt or become extinct.
- These historical events have had long-term consequences for the distribution of species and ecosystems today.
- **Example: Australia's** isolation due to continental drift has led to the evolution of a unique fauna, including marsupials like kangaroos and koalas, which are not found naturally anywhere else in the world.

Climate, altitude, soil types, ocean currents and past events like continental drift and glaciation all have an impact on how life exists on Earth. These factors combine to influence where and how species and ecosystems can exist, highlighting the complexities of Earth's biogeography.

BIOGEOGRAPHIC CLASSIFICATION OF WORLD

The bio-geographical categorization of the planet is a broad issue that includes the **division of the Earth's surface into separate areas, each with its own flora, fauna, and ecological circumstances.** This classification is critical for understanding biodiversity, conservation efforts, and the distribution of various life forms around the globe. The distribution of biodiversity can be classified in the following manner:

Term	Definition	Key Differences
Realm	A realm represents the largest scale of geographical division in biogeography, characterised by distinct sets of flora and fauna.	Realms are the broadest geographical categorizations, reflecting historical, evolutionary, and continental differences. Examples include the Nearctic, Neotropic, and Palearctic realms.
Biome	A biome is a large community of plants and animals occupying a distinct region, defined by its climate and predominant vegetation.	Biomes are defined by specific climatic and geographical conditions that result in unique vegetation patterns. Examples of biomes are tropical rainforests, deserts, and tundras.
Biogeographical Zone	These are regions defined by unique ecological and geographical characteristics, often situated within a larger realm.	Biogeographical zones focus on more specific ecological and geographical characteristics than realms. They include areas like the Mediterranean, Himalayan, and Amazonian zones.
Biodiversity Hotspot	A biodiversity hotspot is a biogeographic region characterised by significant levels of biodiversity that are under threat from human activities.	The presence of numerous endemic species and high levels of human threat serve as indicators of biodiversity hotspots rather than their size or geographic boundaries. Examples include Madagascar, the Caucasus, and Sundaland.

The Eight Biogeographic Realms

Biogeographic domains are **large portions of the Earth's land surface** that have a similar evolutionary history, as evidenced by unique flora and fauna that evolved during long periods of isolation.

Fig. 5.8: The Eight Biogeographic Realms

These worlds are critical for comprehending **global biodiversity patterns** and the historical processes that have shaped them. Each realm, which is further subdivided into ecoregions and biomes, tells a distinct ecological and evolutionary story, showing the diversity of life adapted to its particular environmental conditions.

The Neotropical Realm

- **Location:** It covers the tropical regions of the **Americas, including South America, Central America, the Caribbean, and parts of Mexico and the southern United States.**
- **Characteristics:** The realm is known for having the most extensive **tropical rainforest coverage.** This realm is distinguished by its unique plant and animal species that evolved due to its long-term separation from the Nearctic realm.

The Nearctic Realm

- **Location:** The realm encompasses most of **North America, including Canada, the United States** (excluding southern Florida and Texas), **Greenland, and parts of Mexico.**
- **Characteristics:** It is characterised by a diverse range of habitats and species; this realm is home to unique families of animals such as **canines, equines, and antelopes.**

The Afrotropical Realm

- **Location:** This realm includes **sub-Saharan Africa, southern Arabia, Madagascar, and the western Indian Ocean islands.**
- **Characteristics:** It boasts a wide variety of habitats, from **deserts to forests and savannas,** and is rich in endemic species, including two gorilla and two chimpanzee species.

The Palearctic Realm

- **Location:** It covers **Europe, North Africa** (north of the Sahara), **northern and central Asia,** and the **northern Arabian Peninsula.**
- **Characteristics:** The largest realm, featuring diverse environments such as boreal forests, Mediterranean climates, and deserts. It is home to several endemic animal families.

The Indomalayan Realm

- **Location:** It spans the southern **part of East Asia, the Indian subcontinent, and Southeast Asia.**
- **Characteristics:** It is dominated by **tropical and subtropical forests;** this realm is rich in biodiversity, including many endemic species like the orangutan and the Indian rhinoceros.

The Australasian Realm

- **Location:** The realm includes **Australia, New Guinea, New Zealand, and neighbouring islands.**
- **Characteristics:** Known for its environmental diversity and unique species, some of which are shared with the Indo-Malayan and Antarctic realms due to historical continental connections.

The Oceanian Realm

- **Location: The Pacific Islands,** which include **Hawaii and parts of Micronesia.**
- **Characteristics:** Despite its larger area, it has the smallest land area of all realms, featuring unique island biodiversity and extensive coral reefs like the **Great Barrier Reef.**

The Antarctic Realm

- **Location:** Geographic boundaries include **Antarctica and its surrounding waters.**
- **Characteristics:** The smallest realm, characterised by extreme cold and a landscape of ice, supports specially adapted species such as penguins and seals.

The concept of biogeographic realms provides an intriguing lens through which to view the natural world, emphasising the diversity and uniqueness of life on our planet.

These realms demonstrate how geological history, climate, and evolutionary processes all have a profound impact on biodiversity distribution.

Major Biomes of World

Concept of Biomes

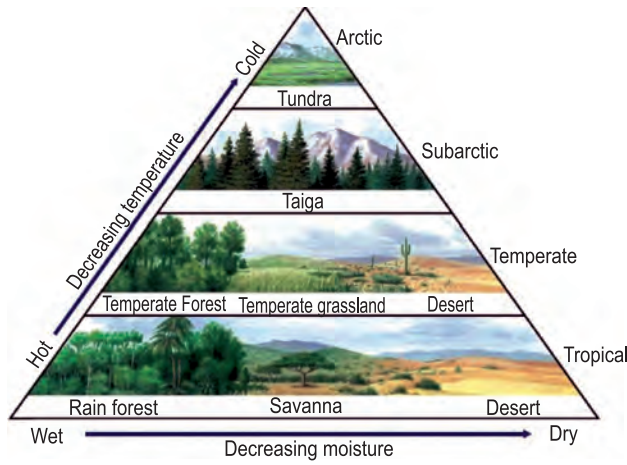


Fig. 5.9: Major Biomes of the World

- **Biomes** are huge groups of plants and animals that live in a particular environment. They are distinguished chiefly by the flora and wildlife that have adapted to the climate and conditions of their surroundings.
- Biomes define distinct ecological groups on Earth by combining the physical terrain (temperature, soil, and water) with living organisms (plants and animals).
- Biomes are more general than ecosystems or habitats; they explain life on a greater scale, covering several ecosystems with similar environmental conditions.

Types of Biomes

Type of Biome	Location Description	Climate Characteristics	Characteristics
Tundra Biomes	Found in the northernmost parts of the globe.	Characterised by long, cold winters and cool summers.	The tundra is a landscape of minimal vegetation, where animals and plants have evolved adaptations like thick fur and hibernation strategies to survive the frigid conditions.
Desert Biomes	Located in both cold and warm climates across the globe.	Defined by their extreme dryness.	Life in desert biomes has adapted to the scarcity of water and nutrients. These adaptations include mechanisms for water storage and water loss.
Grassland Biomes	Present on every continent except Antarctica.	Typically flat and grassy areas with minimal tree cover.	Dominated by grasses, these biomes are home to large grazing mammals, along with a variety of small mammals, birds, and predators, all adapted to open, often dry environments.
Coniferous Forest Biomes (Taigas or Boreal Forests)	Found in northern latitudes.	Long, cold winters, short summers, and significant precipitation are typical.	Conifers and evergreen trees primarily cover these areas. The biome includes adaptations to cold and moisture, with some regions experiencing milder temperatures and being classified as temperate forests.
Temperate Forest Biomes	Located in eastern North America, Western Europe, and northeastern Asia.	These regions are temperate but have a distinct winter season.	Characterised by broad-leafed trees such as maple and oak that lose their leaves seasonally. These forests are rich in biodiversity and have a variety of flora and fauna adapted to the seasonal changes.

Tropical Rainforest Biomes	Situated in equatorial regions.	Warm and wet throughout the year.	They are known for their dense vegetation, which forms a canopy, and high biodiversity. The humid conditions and leaf litter create a nutrient-rich layer above the low-quality soil, supporting a wide variety of plant and animal life.
Aquatic Biomes (Freshwater and Marine)	Covering both freshwater and marine environments, including oceans, lakes, and rivers.	Classified by factors such as water depth, temperature, and salinity rather than climate.	These biomes host diverse life forms adapted to various water conditions. The classification into freshwater and marine types reflects the significant differences in habitat, species, and ecological processes between them.

Biome	Species Examples
Tundra	**Mammals: Polar Bear,** Musk Ox, **Arctic Fox, Reindeer,** and **Wolverine** **Birds:** Snowy Owl, Ptarmigan, Sandhill Crane, Lapland Longspur, Snow Bunting **Reptiles:** Bog Turtle, Viviparous Lizard **Amphibians:** Wood Frog, Northern Leopard Frog, Spotted Frog, Wood Frog, Boreal Toad **Plants: Cotton Grass,** Caribou Moss, **Lichen,** Arctic Poppy, Arctic Willow
Desert	**Mammals:** Fennec Fox, Meerkat, **Kangaroo Rat,** Arabian Oryx **Birds:** Roadrunner, Cactus Wren, Greater Roadrunner, Golden Eagle, Roadrunner, Verreaux's Eagle-Owl **Reptiles:** Gila Monster, **Diamondback Rattlesnake,** Sidewinder Snake, **Horned Lizard,** Thorny Devil **Amphibians:** Spadefoot Toad, Desert Rain Frog, Chiricahua Leopard Frog, Tarahumara Frog, Canyon Tree Frog **Plants:** Saguaro Cactus, Prickly Pear Cactus, Joshua Tree, Creosote Bush, Ocotillo
Grassland	**Mammals:** Pronghorn Antelope, **Bison,** Black-footed Ferret, Greater Prairie Chicken **Birds:** American Kestrel, Meadow Lark, **Burrowing Owl,** Upland Sandpiper, Northern Harrier **Reptiles: Prairie Rattlesnake,** Western Hognose Snake, Gopher Tortoise, Fence Lizard, and Collared Lizard **Amphibians:** Great Plains Toad, Plains Spadefoot Toad, **Tiger Salamander,** Northern Leopard Frog, and Pickerel Frog **Plants:** Big Bluestem Grass, Indian Blanketflower, Switchgrass, Purple Coneflower, Prairie Rose
Coniferous Forest (Taiga/Boreal)	**Mammals: Siberian Tiger,** Wolverine, Lynx, Moose, **Brown Bear** **Birds:** Siberian Jay, Capercaillie, Hazel Grouse, **Siberian Crane**, Black Woodpecker **Reptiles:** Viviparous Lizard, Adder, Slow Worm, **Sand Lizard,** European Glass Lizard **Amphibians: Siberian Salamander,** Fire Salamander, Common Frog, Moor Frog, Pool Frog **Plants:** Scotch Pine, Norway Spruce, Silver Birch, Aspen, Siberian Larch
Temperate Forest	**Mammals: Giant Panda, Red Panda, Koala, Tasmanian Devil** **Birds:** Kakapo, Kea, Tui, Huia (extinct), Spotted Owl and **Kiwi** **Reptiles:** Tuatara, **Komodo Dragon, Alligator Snapping Turtle,** Chinese Crocodile Lizard, **Salamander** **Amphibians: Fire Salamander,** Alpine Newt, Chinese Giant Salamander, Monteverde Poison Frog, Golden Frog **Plants: Redwood Sequoia,** Douglas Fir, Kauri Tree, New Zealand Flax, Pitcher Plant
Tropical Rainforest	**Mammals:** Black Howler Monkey, **Golden-headed Lion Tamarin, Sumatran Orangutan, Three-toed Sloth** **Birds:** Scarlet Macaw, Resplendent Quetzal, Hoatzin, Toucan, Bird-of-Paradise **Reptiles:** Green Iguana, Boa Constrictor, Gila Monster, **Crocodile Monitor, Leatherback Sea Turtle** and **Komodo Dragon,** **Amphibians: Poison Dart Frog**, Red-Eyed Tree Frog, Glass Frog, Axolotl, and Surinam Toad **Plants: Rubber Tree,** Kapok Tree, Rafflesia flower, Victoria amazonica water lily, Cacao tree
Aquatic (Freshwater)	**Fish:** Lake Sturgeon, Mangrove Rivulus, Amazonian Sailfin Catfish, **Giant Mekong Catfish,** African Lungfish **Amphibians:** Axolotl, Lake Titicaca Water Frog, **Chinese Giant Salamander,** Hellbender, Wyoming Toad **Invertebrates: Freshwater Crab, Freshwater Shrimp, Dragonfly,** Mayfly, Stonefly **Plants: Water Lily, Water Hyacinth, Lotus Flower,** Pickerel Weed, Cattail **Algae: Diatoms, Green Algae, Blue-green Algae, Golden Algae, Dinoflagellates**

Biome	Species Examples
Aquatic Marine Biome	**Coral Reefs Fish: Clownfish,** Banggai Cardinal fish, Mandarin Dragonet, Harlequin Shrimp, Bluespine Unicornfish **Invertebrates: Giant Clam,** Staghorn Coral, Brain Coral, Fire Coral, Christmas Tree Worm **Algae: Zooxanthellae** (symbiotic with corals)
	Estuaries Fish: Mangrove Rivulus, Atlantic Sturgeon, California Halibut, **Bull Shark, Diamond Stingray** **Invertebrates: Horseshoe Crab,** Eastern Oyster, Saltmarsh Crab, Fiddler Crab, Mangrove Snails **Plants: Mangrove Trees,** Saltmarsh Cordgrass, Eelgrass, Pickerel Weed, and Sea Lavender
	Open Ocean (Pelagic Zone) **Mammal: Blue Whale Fish: Ocean Sunfish,** Barreleye Fish, **Goblin Shark, Giant Manta Ray** **Invertebrates:** Portuguese Man o' War, **Deep-sea Squid,** Comb Jelly, Salp, Giant Isopod **Plankton: Krill,** Copepods, Diatoms, Foraminifera, and **Dinoflagellates**
	Deep Sea (Benthic Zone) Fish: Viperfish, Anglerfish, **Blobfish, Goblin Shark,** Grenadier Fish **Invertebrates: Giant Squid,** Vampire Squid, Sea Cucumber, **Tubeworm,** Brittle Star **Bacteria:** Extremophiles (adapted to high pressure and temperature)
	Polar Seas Mammals: Walrus, Weddell Seal, Narwhal, **Beluga Whale, Polar Bear** **Birds: Adelie Penguin, Emperor Penguin,** Snow Petrel, Arctic Tern, Ivory Gull **Fish:** Arctic Cod, Greenland Shark, **Lumpfish, Atlantic Salmon, and** Ocean Sunfish

GLOBAL BIODIVERSITY HOTSPOTS

Biodiversity hotspots are distinct areas known for their **high levels of species richness and endemism,** as well as substantial **human-caused concerns.** These regions are crucial for conservation efforts because they maintain intact natural ecosystems in which native animals and communities thrive.

Origin and Criteria of Biodiversity Hotspots

- **Norman Myers** first introduced the idea of biodiversity hotspots in 1988, focusing on tropical forests with high endemism and serious habitat loss.
- **Conservation International (CI)** later adopted and expanded this concept that establishes the criteria for identifying **hotspots:**
  - A region must contain at **least 1,500 species** of vascular plants as endemic, accounting for more than **0.5% of the world's total.**
  - It must have lost at **least 70%** of its original habitat or **retained only 30% or less** of its original natural vegetation.

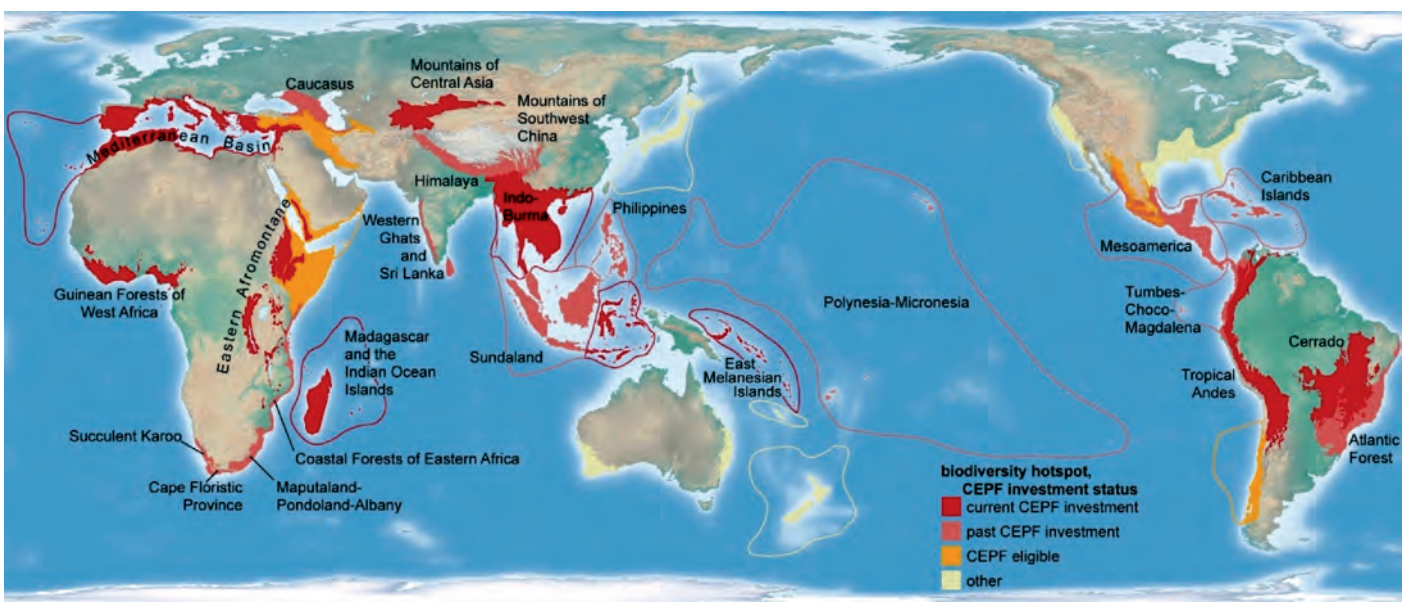


Fig. 5.10: Global Biodiversity Hotspots

Global Distribution and Significance

- There are currently **36 biodiversity hotspots** covering a small fraction of the Earth's land surface.
- These hotspots were once more extensive but have been significantly reduced due to habitat destruction.
- Despite this, they remain home to over **half of the world's plant species** and a significant proportion of terrestrial vertebrate species, highlighting their global conservation importance.

Overview of World Biodiversity Hotspots

- **Africa:** Hosts eight hotspots, including the unique Madagascar and the Indian Ocean Islands, known for their diverse and endemic species.
- **Asia-Pacific:** Features 14 hotspots with significant biodiversity, ranging from the Himalayas to the islands of New Zealand and the Philippines.
- **Europe and Central Asia:** Contains four distinct hotspots, including the Mediterranean Basin, known for its diverse flora and fauna.
- **North and Central America:** Home to several critical habitats, including the California Floristic Province and the Caribbean Islands.
- **South America:** Encompasses hotspots like the Amazon Rainforest and the Tropical Andes, areas of immense biodiversity and endemism.

List of World Biodiversity Hotspots

Region	Biodiversity Hotspots
Africa	Cape Floristic Region, Coastal Forests of Eastern Africa, Eastern Afromontane, Guinean Forests of West Africa, Horn of Africa, Madagascar and the Indian Ocean Islands, Maputaland-Pondoland-Albany, Succulent Karoo.
Asia-Pacific	East Melanesian Islands, Himalaya, Indo-Burma, Japan, Mountains of South-west China, New Caledonia, New Zealand, Philippines, Polynesia-Micronesia, South-west Australia, Forests of Eastern Australia (new), Sundaland, Wallacea, Western Ghats and Sri Lanka
Europe and Central Asia	Caucasus, Irano-Anatolian, Mediterranean Basin, Mountains of Central Asia
North and Central America	California Floristic Province, Caribbean Islands, Madrean Pine-Oak Woodlands, Mesoamerica
South America	Atlantic Forest, Cerrado, Chilean Winter Rainfall-Valdivian Forests, Tumbes-Chocó-Magdalena, Tropical Andes.

Biodiversity Hotspots in India

Only **17 of the world's 200** or so countries have **70% of its biodiversity,** giving them the designation **"megadiverse."** India is one of these megadiverse countries, with **only 2.4% of the world's land area and 4% of fresh water, but 7.3% of documented species,** making it the third most diverse country (after Brazil and Costa Rica), having the highest concentration of species in the **Agasthymalai Hills of the Western Ghats.**

The following are the major biodiversity hotspots in India:

The Himalayan Region Hotspot

- The Himalayan region, spanning across **Bhutan, North-east part of India and parts of Nepal,** is a biodiversity hotspot known for its vast elevation range and diverse ecosystems.
- This area's unique geographical and climatic conditions foster a wide array of habitats and a rich biodiversity.
- **Geographical and Ecological Diversity**
  - **Location:** Encompasses Bhutan, north-eastern India, and southern, central and eastern Nepal.
  - **Ecosystems:** The region's elevation spans from less than **500 meters to over 8,000** meters, creating diverse ecosystems from alluvial grasslands and subtropical broadleaf forests at lower elevations to temperate broadleaf, mixed conifer, and conifer forests in higher areas, culminating in alpine meadows above the treeline.
- **Biodiversity**
  - **Flora and Fauna:** The Himalayas are home to nearly **163 globally threatened species,** including the **vulnerable one-horned rhinoceros** and the **endangered wild Asian water buffalo.**
  - **Plant Diversity:** An estimated **10,000 plant** species thrive here, with **one-third endemic** to the region. It's a center for primitive flowering plants and species of significant economic value, such as rice, banana, citrus, and tea.
  - **Endemic Species:** The area supports unique species across various families, including **Orchidaceae, Zingiberaceae, and Arecaceae,** along with important **gymnosperms and pteridophytes (ferns).**

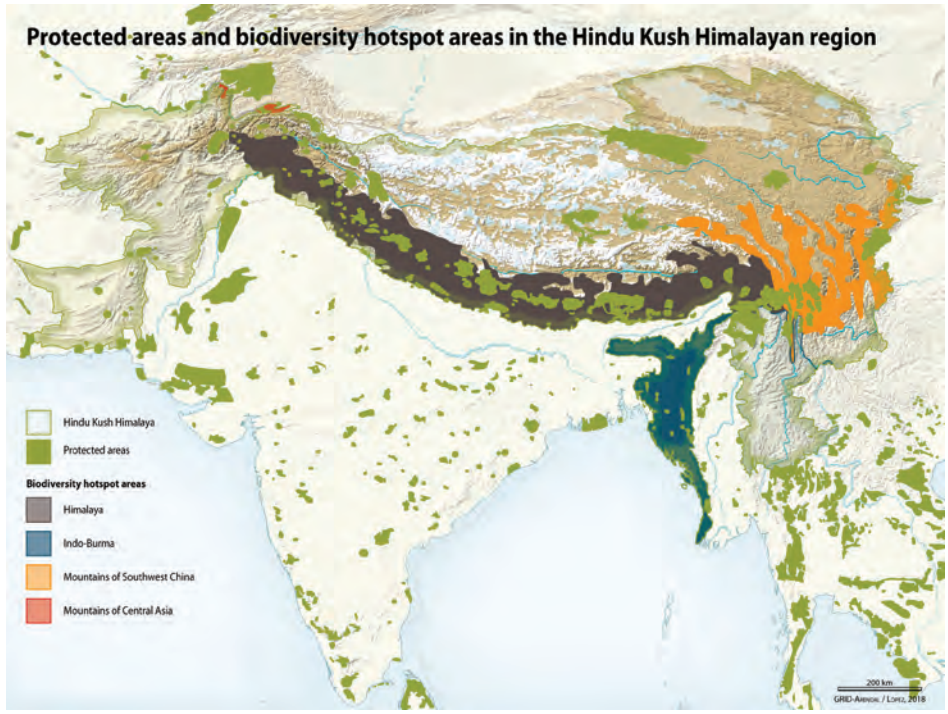


Fig. 5.11: The Himalayan Region Hotspot

- **Agricultural Origins:** Recognised as the origin and diversification center for several palms of commercial importance and the cultivation site for tea for the last **4,000 years.**

❑ **Conservation Concerns**

- **Threatened Species:** The region's biodiversity includes endangered bird species like the **Himalayan Quail, Cheer Pheasant, and Western Tragopan,** alongside significant mammals such as the **Golden Langur, Himalayan Tahr, and Snow Leopard.**
- The Taxol plant, crucial for cancer treatment, is also under threat due to overexploitation.

❑ **Ecological Significance**

- The Himalayas serve as a cradle of speciation and a reservoir for genetic diversity, underscoring the ecological and economic importance of conserving this unique biodiversity hotspot.
- The region's wide range of ecosystems supports a remarkable variety of life forms, making it a priority for conservation efforts to ensure the survival of its unique species and habitats.

Indo-Burma Biodiversity Hotspot

❑ The Indo-Burma region, which spans several countries in **tropical Asia,** is known for its rich biodiversity and complex ecological systems.

❑ This hotspot spans from **Eastern Bangladesh to Malaysia, and includes significant portions of Northeastern India, Myanmar, Southern China, Laos, Cambodia, Vietnam, and Thailand.**

Fig. 5.12: Indo-Burma Biodiversity Hotspot

❑ **Geographical Extent and Habitat Diversity**

- **Location:** Extends from Eastern Bangladesh to Malaysia, covering Northeastern India (south of the Brahmaputra river), Myanmar, Southern China's Yunnan province, Laos, Cambodia, Vietnam, and Thailand.
- **Area and Ecosystems:** Encompassing **over 2 million sq. km,** the region exhibits a wide range of climate and habitat patterns due to its vast area and diverse topography.

❑ **Biodiversity and Conservation Status**

- **Flora:** The hotspot is home to **approximately 13,500 plant species,** with more than half being endemic. Notable for its rich diversity of orchids and ginger species, the region also supports significant populations of tropical hardwood trees, including valuable dipterocarp species and teak.
- **Fauna:** The region supports diverse animal life, including several **primate species** with small populations, such as **monkeys, langurs, and gibbons.** It is also a habitat for nearly **1,300 bird species,** including the **endangered white-eared night-heron and the grey-crowned crocias,** and the near-threatened **orange-necked partridge.** Additionally, many freshwater turtle species are endemic to this area.
- **Environmental Threats:** Rapid **deterioration of natural habitats** has been observed over the past few decades, posing significant threats to the region's biodiversity.

❑ **Ecological Importance and Challenges**

- The Indo-Burma hotspot is a critical area for global biodiversity conservation efforts, given its **high levels of species endemism** and the ecological significance of its varied habitats.
- The conservation of this region is imperative to preserve its unique biodiversity, which is under increasing threat from habitat destruction, overexploitation, and environmental degradation.

Western Ghats and Sri-Lanka Biodiversity Hotspot

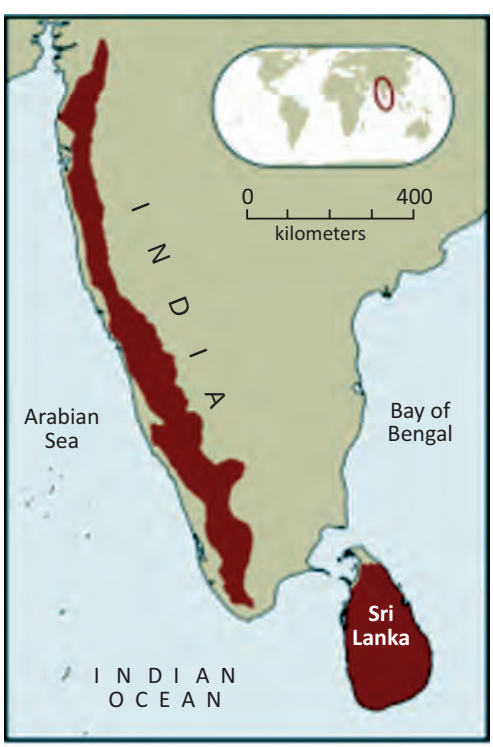


Fig. 5.13: Western Ghats and Sri Lanka Biodiversity Hotspot

❑ The Western Ghats and Sri Lanka region, encompassing the **Sahyadri Hills and the highlands of southwestern Sri Lanka,** is recognised for its exceptional biodiversity and high levels of endemism.

❑ This area is a critical hotspot with unique ecosystems and significant conservation value.

❑ **Geographical Extent**

- **Location:** The Western Ghats stretch across the **southwestern parts of India, while the highlands cover southwestern Sri Lanka.**
- **Ecosystems:** Due to its complex geography and varied rainfall patterns, the area supports a wide variety of vegetation types, which are characterised by moist deciduous forests and rainforests.

❑ **Biodiversity and Endemism**

- **Floral Diversity:** The hotspot is home to **over 6,000 vascular plants** from **more than 2,500 genera,** with **over 3,000 species** being endemic. Notable endemic genera include **Impatiens, Dipterocarpus, and Calamus.** The region is also the origin of many of the world's spices, such as black pepper and cardamom.
- **Faunal Diversity:** The area supports diverse fauna, including endangered species like the **Asian elephant, Nilgiri tahr, and lion-tailed macaque.** It is particularly rich in bird, mammalian, reptilian, and amphibian species, with a significant number of these being endemic to the region.

❑ **Conservation Concerns**

- **Habitat Loss:** Originally covering an area of **about 182,500 square kilometers,** the hotspot's pristine condition has drastically **reduced to 12,445 square kilometers, or 6.8%** of its original extent, mainly due to population pressure and habitat destruction.
- **Threatened Species: Nearly 235 species** of endemic flowering plants are considered endangered. The region's unique biodiversity, including its rare fauna and flora, faces severe threats from deforestation and environmental degradation.

❑ **Ecological Significance**

- **Species Concentration:** The highest concentration of species within the Western Ghats is found in the **Agasthyamalai Hills.** The region is a vital area for conservation, given its role in supporting a vast number of endemic and endangered species.
- **Cross-Border Biodiversity:** The land bridge connection between India and Sri Lanka during past glaciation events has facilitated a **rich exchange of biodiversity,** making the combined region exceptionally significant for conservation.

The Western Ghats and Sri Lanka hotspots stand as a testament to the rich biodiversity of South Asia. Protecting this region is crucial for preserving its unique ecosystems and the myriad of species that call it home.

Sundaland Hotspot

- Sundaland, recognised as one of the most biologically diverse hotspots on the planet, encompasses a significant portion of **Southeast Asia** and is renowned for its unique ecosystems and species richness.
- **Overview of Sundaland**
  - **UN Recognition:** In **2013, the United Nations** designated the islands of **Sundaland as a World Biosphere Reserve,** acknowledging their global ecological importance.
  - **Geographical Extent:** This region spans the western part of the **Indo-Malayan archipelago, including Thailand, Malaysia, Singapore, Brunei, Indonesia, and the Nicobar Islands of India.**

Fig. 5.14: Sundaland Hotspot

- **Ecosystems and Biodiversity**
  - **Terrestrial and Marine Ecosystems:** Sundaland boasts rich **terrestrial and marine ecosystems,** featuring mangroves, coral reefs, and seagrass beds, which support a wide array of life forms.
  - **Floral Diversity:** The hotspot is home to **approximately 25,000 species of vascular plants, 60% of which (about 15,000 species) are endemic.** The **Scyphostegiaceae family, with the Scyphostegia borneensis tree, is exclusive to this region.**
  - **Notable Flora:** Among its remarkable plant species, Sundaland includes **16 species of the genus Rafflesia,** known for producing the **world's largest flowers, such as Rafflesia arnoldii,** which can measure up to one meter in diameter.
  - **Marine Biodiversity:** The region's waters are teeming with diverse marine life, including **whales, dolphins, dugongs, turtles, crocodiles and a variety of fish, prawn, lobster, coral, and seashell species.**
- **Conservation Challenges**
  - **Threats to Biodiversity:** Sundaland's rich biodiversity faces significant threats from the overexploitation of marine resources and the need for protection against deforestation and habitat destruction on its islands.

Sundaland stands as a testament to the incredible biodiversity of Southeast Asia. Its unique species and ecosystems underscore the critical need for conservation efforts to protect and preserve this invaluable global treasure.

Megadiverse Countries

Fig. 5.15: Mega-Diverse Countries of the World

- The concept of **"megadiverse countries"** refers to nations with an exceptionally high number of species, including a significant degree of endemism across various levels of taxonomy.
- These nations, which make up **less than 10% of the planet's surface** but support more than **70% of its biological diversity,** received recognition from the **World Conservation Monitoring Centre in July 2000.**
- **Russell Mittermeier created this idea in 1988** with a primary focus on primate conservation, but it has since expanded to include a wider range of species, such as mammals, birds, reptiles, amphibians, plants, and particular insect groups.
- These countries are characterised by their rich tropical rainforests, coral reefs, and other critical ecosystems.

Criteria of Mega-Diverse Countries

Mega-diverse countries are known for their exceptional biological richness, with a large share of the world's species inhabiting only a fraction of their surface area. These countries are critical to the preservation of global biodiversity because they have distinct habitats and a diverse range of indigenous species.

The criteria for a country to be considered mega-diverse are outlined as follows:

- **Endemic Plants:** The country must have **at least 5,000 endemic plants,** which are species that are not found naturally anywhere else in the world.
- **Marine Ecosystems:** The country must have **marine ecosystems within its borders,** indicating a diversity that extends from land to marine environments.

Mega-diverse countries are important beyond their boundaries because they contribute significantly to global biodiversity and ecological equilibrium. Protecting these countries' natural legacy is critical for preserving the planet's health and the well-being of future generations, underscoring the importance of global conservation initiatives.

STATUS OF GLOBAL BIODIVERSITY LOSS

The **state of global biodiversity** is facing an unprecedented crisis, characterised by the rapid disappearance of species and significant declines in population sizes and habitats. The **sixth mass extinction** event in Earth's history has begun, and human activity is the main cause of this crisis. Below is a detailed explanation of the current status of global biodiversity loss:

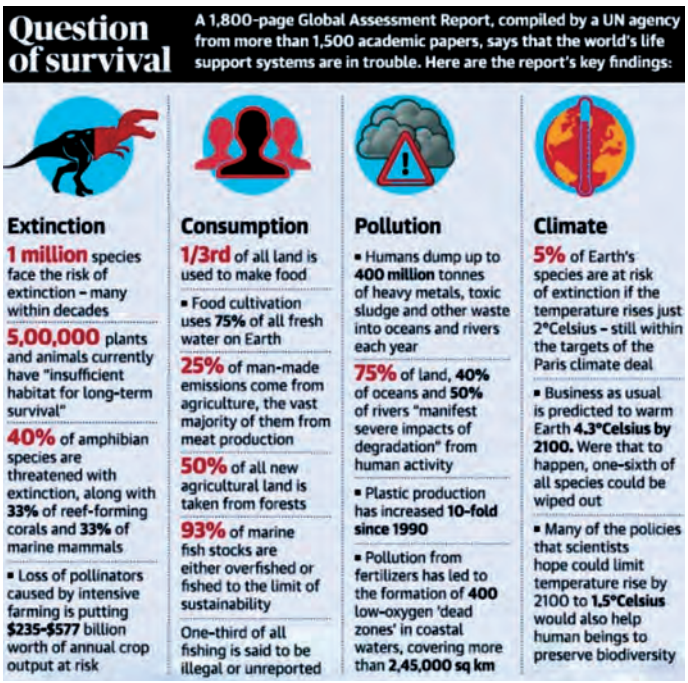

Question of survival
A 1,800-page Global Assessment Report, compiled by a UN agency from more than 1,500 academic papers, says that the world's life support systems are in trouble. Here are the report's key findings:
Extinction
1 million species face the risk of extinction – many within decades
5,00,000 plants and animals currently have "insufficient habitat for long-term survival"
40% of amphibian species are threatened with extinction, along with 33% of reef-forming corals and 33% of marine mammals
Loss of pollinators caused by intensive farming is putting $235-$577 billion worth of annual crop output at risk
Consumption
1/3rd of all land is used to make food
Food cultivation uses 75% of all fresh water on Earth
25% of man-made emissions come from agriculture, the vast majority of them from meat production
50% of all new agricultural land is taken from forests
93% of marine fish stocks are either overfished or fished to the limit of sustainability
One-third of all fishing is said to be illegal or unreported
Pollution
Humans dump up to 400 million tonnes of heavy metals, toxic sludge and other waste into oceans and rivers each year
75% of land, 40% of oceans and 50% of rivers "manifest severe impacts of degradation" from human activity
Plastic production has increased 10-fold since 1990
Pollution from fertilizers has led to the formation of 400 low-oxygen 'dead zones' in coastal waters, covering more than 2,45,000 sq km
Climate
5% of Earth's species are at risk of extinction if the temperature rises just 2°Celsius – still within the targets of the Paris climate deal
Business as usual is predicted to warm Earth 4.3°Celsius by 2100. Were that to happen, one-sixth of all species could be wiped out
Many of the policies that scientists hope could limit temperature rise by 2100 to 1.5°Celsius would also help human beings to preserve biodiversity

Fig. 5.16: Extent of Biodiversity Loss

Extent of Biodiversity Loss

- **Species Under Threat:** Currently, an **estimated 1.2 million plant and animal** species are under threat of extinction **by the year 2100.** This includes groups particularly vulnerable to extinction, such as **amphibians, cycads, and corals.**
- **Historical Extinctions:** Since the **16th century,** the world has lost **at least 680 vertebrate species** and **nearly 600 plant species.** The current rate of species extinction is **10 to 1,000 times faster** than the natural background rate.
- **Population Declines and Range Contractions:** The **World Wide Fund for Nature's Living Planet Report 2022 documents a 69% average decline** in the abundance of mammals, birds, reptiles, fish and amphibians since **1970, with an 83% decline** in freshwater vertebrates over the same period.

Geographic Distribution of Losses

- **Global South:** The majority of recent biodiversity losses have occurred in **low and middle-income countries,** particularly in **Latin America,** where the effects of human activities on biodiversity are most pronounced.
- **Northern Hemisphere:** Countries in the **Northern Hemisphere** have suffered less severe recent losses, largely because many of their natural ecosystems had already suffered significantly from historical activities.

Drivers of Biodiversity Crisis

- **Habitat Loss, Degradation, and Fragmentation:** The primary cause of biodiversity loss is the **destruction, degradation, and fragmentation** of habitats due to industrial activities, agriculture and urban expansion, driven by high-consumption lifestyles and rising consumption globally.

- **Climate Change:** Climate change is emerging as a leading cause of biodiversity loss, altering ecosystems, species distributions, and ecological processes, and is expected to become the main driver as it intensifies.
- **Other Human Drivers: Overfishing, overhunting, the spread of invasive species, and diseases** are significant drivers of biodiversity loss. International trade, habitat destruction, and various forms of pollution exacerbate these.

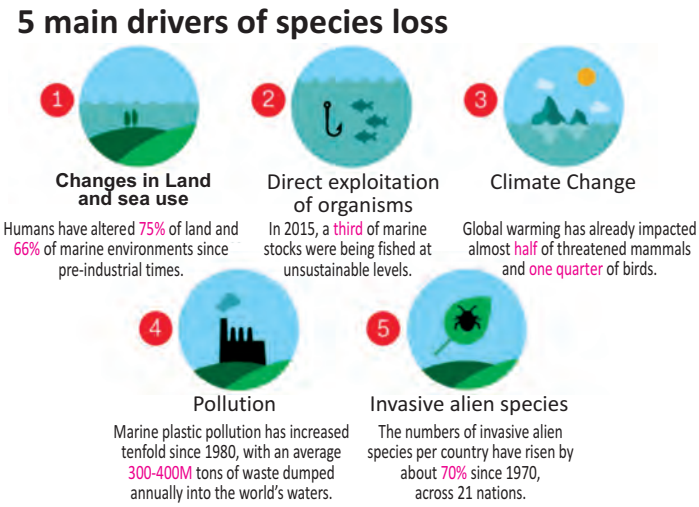

5 main drivers of species loss
1
Changes in Land and sea use
Humans have altered 75% of land and 66% of marine environments since pre-industrial times.
2
Direct exploitation of organisms
In 2015, a third of marine stocks were being fished at unsustainable levels.
3
Climate Change
Global warming has already impacted almost half of threatened mammals and one quarter of birds.
4
Pollution
Marine plastic pollution has increased tenfold since 1980, with an average 300-400M tons of waste dumped annually into the world's waters.
5
Invasive alien species
The numbers of invasive alien species per country have risen by about 70% since 1970, across 21 nations.

Fig. 5.17: Drivers of Biodiversity Crisis

Specific Impacts

- **Freshwater Ecosystems:** Freshwater vertebrates have seen an **83% decline in populations,** highlighting the vulnerability of freshwater ecosystems.
- **Insects and Plants:** In some regions, such as Germany, there has been a documented decline of **around 70% in plant species since the 1960s and a more than 75% reduction in the weight of flying insects** in protected areas in less than three decades.
- **Coral Reefs:** Coral reefs are among the most biodiverse ecosystems on Earth, **which may face upto 99% risk of disappearance** if global temperature rise is not kept below **1.5°C above pre-industrial levels.**

Mass Extinctions

- Mass extinction is defined as a period with significantly higher extinction rates than normal, where at least **75% of species go extinct within a relatively short period of time,** typically less than two million years. These events are characterised by both their magnitude—the percentage of species lost—and the rate at which this loss occurs.
- **The "Big Five" Mass Extinctions**
  - **End-Ordovician extinction (444 million years ago; mya):** resulted in the **loss of 86% of species,** driven by intense glacial and interglacial periods that caused large sea-level swings and dramatic changes in climate and ocean chemistry.
  - **Late Devonian (360 mya):** saw **75% of species go extinct,** likely due to the rapid growth and diversification of land plants that led to severe global cooling.
  - **End-Permian extinction (250 mya):** The most severe, with **96% of species lost,** attributed to intense volcanic activity in Siberia that caused global warming, ocean acidification, acid rain, and drastic changes in ocean and land chemistry.
  - **End- Triassic/Jurassic extinction (200 mya):** resulted in **80% species loss,** likely due to underwater volcanic activity in the **Central Atlantic Magmatic Province (CAMP)** that led to global warming and significant changes in ocean chemistry.
  - **End- Cretaceous extinction (65 mya): Known for the extinction of the dinosaurs, with 76% of species lost**
- **The Sixth Mass Extinction**
  - The concept of a **sixth mass extinction** is based on the current, unprecedented rate of species extinctions, which is believed to be **driven by human activities.**
  - Unlike the natural events that triggered the previous mass extinctions, the sixth mass extinction is characterized by factors such as **habitat destruction, pollution, climate change, overfishing and hunting,** leading to a rapid decline in biodiversity.
  - The current trajectory of species loss suggests that we may be on the brink of another mass extinction event, the outcome of which depends on human actions to conserve biodiversity and mitigate environmental impacts.

The current global biodiversity crisis underscores the urgent need for comprehensive and coordinated global conservation efforts to safeguard the natural world and ensure the well-being and survival of human societies.

IGNITE YOUR MIND

The Silent Vanishing: A Race Against Time:
Throughout history, Earth has witnessed mass extinctions, like the disappearance of the dinosaurs. But the current rate of species loss is breaking records! Explore the different types of extinction and why this ongoing crisis should concern us all.

Causes of Global Biodiversity Loss

Various **human activities and environmental changes** are the main causes of biodiversity loss, a serious global issue. The following is a detailed breakdown of the top causes leading to the decline in biodiversity:

- **Habitat Loss and Fragmentation**
  - **Conversion of Natural Habitats:** The transformation of natural areas into agricultural lands, urban spaces, and infrastructural developments significantly contributes to habitat destruction and fragmentation.

- **Impact on Native Species:** This reduction in natural habitats limits the space for native species to live, feed, and reproduce, disrupting the ecological balance.

❑ **Climate Change**
- **Altered Habitats:** Global warming and shifts in climate patterns have modified habitats, challenging the survival and adaptation of many organisms.
- **Temperature and Rainfall Changes:** These climatic alterations affect the growth and survival of various plant species, impacting the dependent fauna.

❑ **Overhunting**
- **Demand for Resources:** The excessive hunting of species for meat, byproducts, sport, or pest control leads to rapid population declines and potential extinction.
- **Industrialised Hunting:** This practice overlooks the ecological consequences of species depletion, affecting entire ecosystems.

❑ **Overfishing**
- **Depletion of Marine Species:** Industrial fishing practices have overexploited species like **tuna, whales, and salmon,** meeting global demand but leading to significant biodiversity loss.
- **Destruction of Habitats:** Techniques such as bottom trawling have damaged sea-floor habitats, crucial for many marine species' survival.

❑ **Invasive Species**
- **Disruption of Ecosystems:** Non-native species introduced to new environments can outcompete indigenous species for resources, leading to ecological imbalances.
- **Predation and Disease Transmission:** Invasive species can prey on native species or introduce diseases, further destabilising ecosystems.

❑ **Pollution**
- **Habitat Degradation:** Pollution of air, soil, and water degrades habitats, directly harms species, and increases their vulnerability to diseases and predators.
- **Bioaccumulation:** Pollutants like pesticides and heavy metals can accumulate through the food chain, affecting multiple ecosystem levels.

❑ **Disease**
- **Spread of Infectious Diseases:** Diseases, often spread through human activities, can devastate wildlife populations, especially when ecosystems are contaminated with non-native microbes.

❑ **Genetic Pollution**
- **Loss of Genetic Diversity:** The introduction of genetically modified organisms or hybridization can reduce genetic diversity, which is crucial for species' adaptability and resilience.

❑ **Ocean Acidification**
- **Impact on Marine Organisms:** Increased carbon dioxide levels lead to ocean acidification, harming organisms like **corals, plankton, and shellfish** by affecting their ability to maintain protective coatings.

❑ **Ecosystem Simplification**
- **Conversion to Monocultures or Urban Areas:** Simplifying complex ecosystems into less diverse ones reduces available niches for species and decreases overall ecosystem resilience.

These causes of biodiversity loss highlight the interconnectedness of ecosystems and the far-reaching impacts of human activities on the planet's biological diversity. Addressing these issues requires concerted global efforts towards conservation and sustainable practices.

IGNITE YOUR MIND

A United Effort for a Healthy Planet:

Protecting biodiversity is a global mission, not a solo quest! Explore key international initiatives, like the Convention on Biological Diversity, and understand how they contribute to this vital mission. How can we work together across borders to protect our shared planet?

Climate Change and Its Impact on Global Biodiversity

Climate change is a global phenomenon that has **far-reaching implications** for the planet's biogeography, influencing species distribution, biome integrity, and conservation efforts. Climate change's rising temperatures, shifting precipitation patterns, and increased frequency of extreme weather events are fundamentally altering the natural world.

Effects on Species Distribution

❑ **Shifts in Habitat Ranges:** Many species are moving towards **higher latitudes and altitudes** in search of suitable climate conditions. This shift can lead to mismatches between species and their historical ranges, affecting ecosystem dynamics and species interactions. For example, plant species that cannot migrate quickly enough may face extinction, while animal species may find new competitors and predators in their new ranges.

❑ **Phenological Changes:** The timing of biological events, such as **flowering, breeding, and migration,** is being altered. These changes can disrupt the synchrony between species, such as pollinators, and the plants they pollinate, leading to declines in both populations.

- **Ocean Acidification and Warming:** Marine species are particularly vulnerable to climate change. Ocean acidification, resulting from **increased CO_2 levels,** affects calcifying organisms like corals and shellfish. Warming oceans lead to coral bleaching and shifts in the distribution of fish species, impacting fisheries and livelihoods.

Human Wildlife Conflict

- **Altered Habitats:** Climate change affects the **availability of natural habitats for wildlife. As temperatures rise and precipitation patterns change,** animals may be forced to move into human-dominated landscapes in search of food, water, and shelter, leading to increased encounters with humans.
- **Shifted Animal Ranges:** Many species are shifting their geographic ranges **towards the poles or to higher elevations** in response to changing climates. This movement can bring animals into closer contact with human communities, particularly at the edges of urban and agricultural areas.
- **Resource Scarcity:** Climate change can exacerbate resource scarcity, making food and water more difficult to find for both humans and wildlife. **Competition over these scarce resources** can lead to conflict, especially in areas where humans and wildlife have previously coexisted peacefully.
- **Increased Predation on Livestock:** As wild prey becomes scarcer due to habitat changes, predators may turn to livestock as an alternative food source, leading to economic losses for farmers and **retaliatory killings of predators.**
- **Disease Transmission:** Changes in climate and habitat can also alter the patterns of **diseases among wildlife, livestock, and humans.** Increased contact between wildlife and humans raises the risk of disease transmission, which can further strain human-wildlife relations.

Impact on Biomes

- **Forest Biomes: Increased temperatures and changes in precipitation** are affecting forest health and productivity. Drier conditions increase the risk of wildfires, while warmer temperatures facilitate the spread of pests and diseases. Tropical forests, such as the **Amazon,** are experiencing both deforestation and climate-induced stresses, potentially tipping them towards becoming net carbon sources rather than sinks.
- **Arctic and Alpine Biomes:** These biomes are among the most affected by climate change, with **melting ice and snow altering** habitats. The retreat of glaciers and sea ice affects species dependent on these environments, such as polar bears and seals. The thawing of permafrost releases greenhouse gases, further exacerbating global warming.
- **Grasslands and Savannas:** Changes in rainfall patterns and increased temperatures affect the productivity and composition of grassland ecosystems. This can lead to **desertification** in some areas and changes in the types of grasses that dominate, affecting the herbivores that rely on them.
- **Coral Reefs:** Coral reefs are highly **sensitive to temperature changes.** Warming seas cause coral bleaching, where corals expel the algae living in their tissues, leading to a decline in coral health and the ecosystems they support.

Conservation Challenges

- **Adaptation and Management:** Conservation strategies must now account for the dynamic nature of ecosystems under climate change. This includes facilitating species **migration** through wildlife corridors, safeguarding climate refugia, and considering assisted migration for species that cannot migrate on their own.
- **Protecting Biodiversity Hotspots:** Biodiversity hotspots are particularly vulnerable to climate change. Conservation efforts need to focus on these areas to preserve the planet's biodiversity, which includes **prioritising the protection of habitats** that are most likely to offer refuge to a wide range of species.
- **International Cooperation:** Climate change is a global issue that requires international cooperation. Agreements like the **Paris Agreement** are crucial for setting global targets for reducing greenhouse gas emissions. Conservation efforts must be coordinated across borders to address the challenges posed by shifting species distributions and changing ecosystems.
- **Integrating Climate Change into Conservation Planning:** Conservation planning must incorporate climate change projections to ensure the long-term effectiveness of protected areas and other conservation measures. This involves using climate models to predict future changes in habitats and species distributions and planning accordingly.

Climate change is altering the Earth's biogeographic patterns in unprecedented ways, posing significant conservation challenges. To address these challenges, a multifaceted approach that combines scientific research, innovative conservation strategies and global cooperation is required to mitigate the effects of climate change on the natural world.

Bioprospecting

- **Definition:** Bioprospecting is a **systematic and organised** approach to discovering valuable products derived from **bioresources, including plants, microorganisms, and animals.**
  - This process is aimed at further development for commercialization, benefiting society at large.
  - It involves the search, collection, and derivation of genetic material from samples of biodiversity for use in pharmaceutical, agricultural, industrial, or chemical processing products.
- **Background**
  - Traditionally, nature has been the primary source of medicinal compounds, with many significant drugs being derived from natural sources.
  - Examples include **morphine, quinine, and digitoxin,** among others.
  - These discoveries underscore the importance of natural products in the development of therapeutic agents and highlight the ongoing relevance of bioprospecting in drug discovery and research.
- **Biodiversity in Bioprospecting**
  - Bioprospecting emphasises the importance of **genetic, species, and ecosystem biodiversity.**
  - It plays a crucial role in monitoring and preserving biodiversity, facilitating technology and knowledge transfer, promoting innovation, and supporting conservation efforts.
- **Benefits and Processes**
  - Bioprospecting offers numerous benefits, including the potential for **economic development** through the sustainable use of bio-resources the preservation of traditional cultures and practices, and the advancement of medical and agricultural technologies.
  - The bioprospecting process typically involves several phases, from the on-site collection of samples and isolation of specific compounds to screening for uses, product development, and commercialization.
  - This structured approach ensures the potential for generating new products and income while providing incentives for biodiversity conservation.
- **Drug Discovery through Bioprospecting:** Several drugs have been developed through bioprospecting, demonstrating the diversity of natural sources and their contributions to medical science. Notable examples include:
  - **Morphine,** derived from Papaver somniferum, used for pain management.
  - **Aspirin,** originating from Spirea ulmaria, known for its analgesic, anti-inflammatory and antipyretic properties.
  - **Quinine,** from Cinchona officinalis, used primarily for treating malaria.
  - **Artemisinin,** discovered in Artemisia annua, a key drug used for treating malaria.
  - **Vinblastin,** from Catharanthus roseus, utilised in chemotherapy.

Bioinformatics

- **Definition:** Bioinformatics uses **computer technology** to manage and analyse biological data. This field has become essential in interpreting the data from various biological studies, including genomics, proteomics, and other forms of high-throughput biology.
  - It enables researchers to recognise **patterns** and make discoveries that would be difficult or impossible to achieve manually, thanks to advancements in **computational tools** and the increased capacity for data storage and analysis.
- **Background**
  - The roots of bioinformatics trace back to the early 1960s, with efforts to decipher the **molecular sequences of proteins.**
  - The advent of modern computing transformed the manual processes of assembling, analysing, and comparing protein sequences, leading to the development of methods to manipulate and analyse molecular sequences digitally.
  - A landmark in bioinformatics was the **Human Genome Project (1990-2003),** which **sequenced the 3.1 billion protein base pairs of the human genome,** a task that would have been unfeasible without bioinformatics tools.
- **Applications and Benefits**
  - Bioinformatics is important in analysing and interpreting the deluge of biological data produced by **contemporary research.**
  - It has facilitated rapid advancements in understanding diseases, such as **sequencing the coronavirus genome** and developing vaccines within months.
  - Bioinformatics tools, including **data mining, pattern recognition, visualisation, and machine learning,** enable researchers to design targeted experiments, discover genes responsible for diseases, and understand immune responses to pathogens.
- **Challenges and Limitations**
  - Despite its transformative potential, bioinformatics faces limitations, including the need for **domain-specific biological knowledge** to interpret data patterns and the computational resources required for data analysis.
  - Collaboration across different research domains is often necessary to fully leverage bioinformatics in experimental research.

Bioinformatics Contribution to Biodiversity Research

- **Surveying and Assessing Biodiversity:**
  - Bioinformatics tools expedite the analysis of environmental samples, such as **DNA extracted from soil or water,** enabling rapid species identification and abundance estimation.
  - This approach surpasses traditional methods like morphological identification in speed and efficiency.
- **Exploring Evolutionary Relationships:** Analysis of DNA sequences facilitates the reconstruction of evolutionary histories and the construction of **phylogenetic trees,** elucidating relationships among different organisms.
- **Monitoring Ecosystem Health:**
  - By scrutinizing changes in species composition over time, bioinformatics aids in gauging the impact of factors like **climate change** and **pollution** on biodiversity.
  - This monitoring helps in assessing the health of ecosystems and identifying areas requiring conservation efforts.
- **Informing Conservation Strategies:**
  - Bioinformatics assists in identifying threatened or endangered species and prioritizing conservation areas.
  - It also aids in tracking the effectiveness of **conservation programmes,** contributing to informed decision-making in biodiversity conservation.

In essence, bioinformatics serves as a cornerstone for unraveling the intricacies of life's diversity, enabling scientists to comprehend and manage the planet's rich biodiversity effectively.

Biopiracy

- **Definition:** Biopiracy refers to the **exploitation of traditional knowledge and biological resources** by corporations and individuals for profit, often without fair compensation to the indigenous knowledge holders.
  - This exploitation not only undermines the rights of **indigenous communities** but also threatens biodiversity and traditional knowledge systems.
  - The loss of biodiversity, disruption of traditional knowledge **systems, genetic erosion, inequitable benefit distribution, and lack of sustainability** are among the adverse effects of biopiracy.
- **Example**
  - Instances of biopiracy include the **commercial patenting of turmeric's medicinal properties** and **neem oil's use by foreign entities**, despite their long-standing use in traditional Indian medicine.
  - These cases highlight the broader issue of misappropriating traditional knowledge for commercial gain without due recognition or compensation to the indigenous communities.
- **Unethical Practices:**
  - Encompasses **unauthorized activities** like collection, use, and commercialization of genetic materials.
  - Often results in **violations of intellectual property rights (IPR).**
  - Fails to share benefits fairly with the **local communities.**
  - Poses a significant threat to **biodiversity conservation** and may lead to **habitat destruction.**
- **Impact on Biodiversity:**
  - Poses a direct threat to **biodiversity conservation.**
  - Carries the potential for **habitat destruction.**
- **Legal and Protective Mechanisms**
  - India has implemented several measures to protect traditional knowledge and address biopiracy.
  - The **Biological Diversity Act of 2002** controls access to genetic materials and the traditional knowledge that goes with them.
  - The **Patents Act of 1970** lets patents that are based on traditional knowledge be turned down.
  - Other important steps include creating the **Traditional Knowledge Digital Library (TKDL)** to record and protect traditional knowledge and protecting products that are only found in certain areas.
- **International Legal Framework**
  - The international legal regime related to biodiversity includes the **Convention on Biological Diversity (CBD)** and the **Nagoya Protocol.**
  - These agreements aim to promote the conservation of biodiversity, the sustainable use of its components, and the equitable sharing of benefits arising from the utilisation of genetic resources, recognising the vital role of traditional knowledge in biodiversity conservation.
- **Recommendations for Protection**
  - To enhance the protection against biopiracy, it is recommended to improve the **effectiveness of existing databases** like the TKDL, establish clear criteria for resource utilisation by indigenous populations, and incorporate legal provisions for initiating lawsuits against biopiracy.
  - Additionally, prioritising the conservation of natural resources and traditional knowledge in government plans, identifying and promoting local traditional knowledge practices, and establishing special tribunals for disputes involving traditional knowledge are crucial steps.

IGNITE YOUR MIND

Beyond Exploitation: Sharing Nature's Bounty Fairly

Imagine finding a treasure chest, but only one person gets to keep everything! The resources found in diverse ecosystems raise ethical concerns. Investigate the concept of biopiracy and discuss how we can ensure fair and sustainable utilization of biodiversity for everyone's benefit.

Hope Spots

- Hope spots are specific areas of the ocean identified for special protection due to their **wildlife and significant underwater habitats.** These areas are critical for the conservation of marine biodiversity.
- **Examples:** The **Andaman and Nicobar Islands, along with the Lakshadweep Islands,** have been designated as hope spots by the **International Union for Conservation of Nature (IUCN)** and **oceanographer Sylvia Earle's Mission Blue.** These regions are recognised for their unique marine and terrestrial biodiversity, including sensitive coral reefs that require urgent protection.
- Creating more Hope Spots and supporting our existing Hope Spots allow us to move closer to achieving our goal of protecting 30% of the oceans by 2030. These areas not only support a vast array of species and habitats but also provide essential ecosystem services that are vital for human survival and cultural heritage.

IGNITE YOUR MIND

The Puzzle of Planet Earth:

Imagine Earth as a giant puzzle, with each piece representing a unique biome, like a scorching desert or a lush rainforest. Explore the factors that influence where different species live on this puzzle and why understanding these patterns is crucial for protecting them. Is there a reason some areas teem with life, while others seem almost barren?

Cold Spots

- This term refers to an area with a limited variety of living things, including **plants, animals, fungi, and bacteria. It signifies regions where biodiversity is low.**
- Cold spots are regions critical for both global and local ecosystem processes, which harbour unique evolutionary lineages, rare species and encompasses significant wilderness landscapes.
- These regions support a wide variety of animal species because interactions **between at least one species affect its fitness.**
- Additionally, cold spots often exist within national policy environments that are more conducive to conservation success.
- Consequently, all cold spots would gain from enhanced protection, conservation management and restoration efforts.

BIOGEOGRAPHICAL CLASSIFICATION OF INDIA

India's biogeographical classification reflects the country's diverse ecosystems, which range from the Himalayan mountains to the coastal regions, as well as dense forests and arid deserts. This diversity stems from India's vast geographical spread, varied topography, and climatic variations.

Geographical Location and Topography

- India is a country in South Asia and has borders with **Pakistan to the northwest, China, Nepal, and Bhutan to the north, Bangladesh, and Myanmar to the east.**
- The Indian Ocean borders it to the south. The country's topography is diverse, featuring the Himalayan mountain range in the north, the **Thar Desert** in the west, the Indo-Gangetic Plains, and a long coastline along the Indian Ocean.
- This diverse topography contributes to varied ecosystems across the country, from snow-capped mountains to lush forests and arid deserts.

Climate Variability Across Regions

- India's climate is equally varied due to its vast size and topographical diversity.
- It ranges from a **tropical monsoon climate in the south to temperate climate in the north.**

Fig. 5.18: India's Biogeography

- The country experiences four main seasons: winter (January and February), summer (March to May), a monsoon or rainy season (June to September), and a post-monsoon period (October to December).
- The climate varies significantly across regions, influencing the distribution and types of flora and fauna found in each area.

Significance of India's Biodiversity

- India is one of the **17 mega-diverse countries** in the world, hosting about **7-8% of all recorded species, including over 45,000 species of plants and 91,000 species of animals.**
- Its forests, wetlands, deserts and mountains are home to a myriad of species, some of which are endemic to the region.
- The **Western Ghats, Eastern Himalayas, and Sundarbans** are recognised as biodiversity hotspots.
- India's biodiversity is not only crucial for the environment but also supports livelihoods and contributes to the economy through agriculture, forestry, fisheries and tourism.

IGNITE YOUR MIND

Earth's Bio-Gems Under Threat:

Have you heard of hidden treasures? Some areas on Earth, like the Western Ghats in India, are biodiversity hotspots, holding a treasure trove of species in a small area. Why are these hotspots so special, and what are the consequences if we lose these gems forever?

Factors Influencing India's Unique Biogeographic Regions

A variety of factors shape India's bio-geographical regions, resulting in a mosaic of ecosystems across the nation.

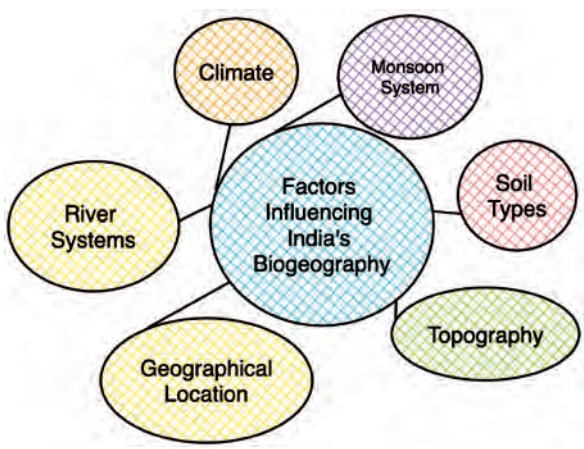


Fig. 5.19: Factors Influencing India's Biogeography

- **Geographical Location:** India's position between the **Arabian Sea to the west and the Bay of Bengal to the east,** along with its vast latitudinal spread from the Himalayas in the North to the tropical Indian Ocean in the South, plays a crucial role in its bio-geographical diversity.
- **Topography:** The Himalayas, the Western and Eastern Ghats, and the vast Indo-Gangetic plains significantly influence **climate patterns, rainfall distribution,** and, thus, the type of vegetation and wildlife found in these regions.
- **Climate:** The wide range of climates, from tropical in the south to temperate in the north, including desert climates in the west and humid tropical climates in the north-east, dictates the distribution of **different ecosystems** across India.
- **Monsoon System:** The **monsoon winds** bring significant rainfall to most parts of the country, affecting agricultural patterns, water availability, and the types of forests and animal species in various regions.
- **Soil Types:** The diversity of soil types, from **fertile alluvial soils** in the plains to **red and laterite soils** in the plateau regions, influences the type of vegetation and agricultural practices in different areas.
- **River Systems:** The extensive network of rivers, including the **Ganges, Brahmaputra, and Godavari,** supports diverse aquatic ecosystems and influences the surrounding terrestrial biodiversity.

One of the world's biodiversity hotspots, India's bio-geographical richness is a result of its distinctive geographic location, diverse topography, climate, monsoon patterns, soil types, and river systems. These elements contribute to the country's diverse ecosystems, which support a wide range of flora and wildlife.

INDIA'S BIODIVERSITY: REALMS, BIOMES AND ZONES

- India's biodiversity reflects its wide and diverse geography, which ranges from the towering Himalayas in the north to the tropical rainforests of the south, and from the barren deserts of the west to the lush Eastern Ghats.
- This diversity is divided into: **five primary biomes, ten biogeographic zones, and twenty-five biogeographic provinces,** each with distinct ecological, climatic, and physical qualities that sustain a diverse range of flora and fauna.
- This classification emphasises not only the diversity of India's natural heritage, but also the importance of protecting its distinct ecosystems.
- The following overview digs into the realms, biomes, zones, and provinces that contribute to India's biodiverse status, providing insights into the complexity and variety of its natural ecosystems.

❑ **Two Realms**

- **Palearctic Realm:** This region represents the **Himalayan region,** characterised by a unique set of flora and fauna adapted to the cold and mountainous environment.
- **Malayan Realm:** Encompasses the **rest of the Indian subcontinent,** featuring a diverse range of ecosystems, from tropical forests to arid deserts.

❑ **Five Biomes**

- **Tropical Humid Forests:** Rich in biodiversity, these forests are found in areas with high rainfall and temperatures.
- **Tropical Dry or Deciduous Forests (including Monsoon Forests):** It is characterised by a season of drought and a season of rain, supporting a wide variety of plant and animal life.
- **Warm Deserts and Semi-deserts:** They are areas with low precipitation and sparse vegetation, adapted to arid conditions.
- **Coniferous Forests:** Found in the **higher altitudes,** these forests are dominated by coniferous trees.
- **Alpine Meadows:** Located at the **highest altitudes,** these meadows have unique flora and fauna adapted to cold climates.
- **Ten Biogeographic Zones:** Trans-Himalayas, Himalayas, Desert, Semi-Arid, Western Ghats, Deccan Peninsula, Gangetic Plain, North-East India, Islands and Coasts.

Each zone is distinct in terms of its climate, geography, and the biodiversity it supports, from the snow-covered peaks of the Himalayas to the lush greenery of the Western Ghats and the unique island ecosystems.

Biogeographic Zones Across India

India's biodiversity is divided into **10 biogeographic zones,** each with its own set of climatic conditions, geographical features, and diverse flora and fauna. These are:

1. The **Trans-Himalayan Zone,** known for its cold desert landscapes in Ladakh and parts of Himachal Pradesh, harbours unique high-altitude ecosystems with species such as the Snow Leopard and Wild Yak.
2. Adjacent to this is the **Himalayan Zone,** stretching across the northern boundary, which boasts a variety of ecosystems, from alpine meadows to subtropical forests, home to the Bengal Tiger and Red Panda.
3. The **Indian Desert, or the Thar Desert,** characterised by its sandy terrain and sparse vegetation, supports species adapted to arid conditions like the Indian Gazelle.
4. Below it, the **Semi-Arid Zone** includes parts of Punjab and Maharashtra, with dry deciduous forests and grasslands.

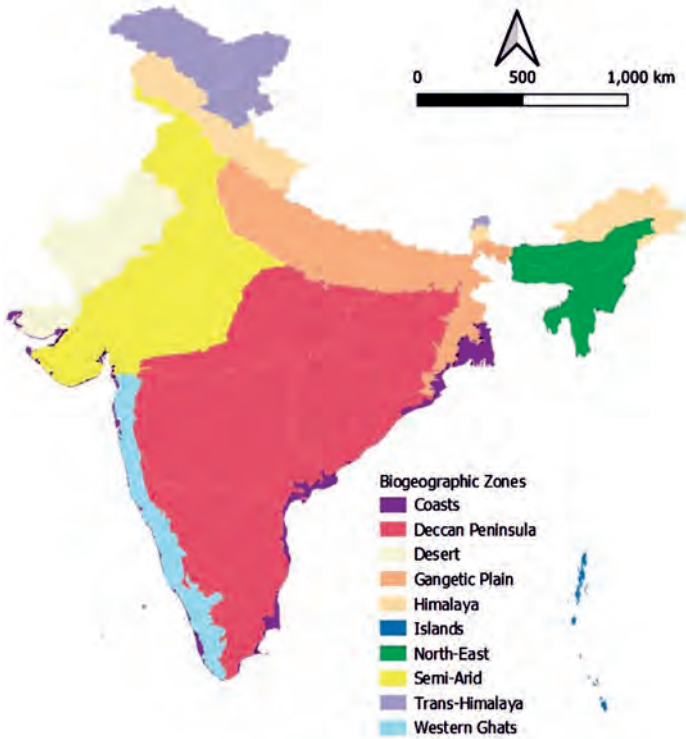


Fig. 5.20: Indian Biogeographic Zones

5. The **Western Ghats**, a biodiversity hotspot along the west coast, feature montane rainforests teeming with endemic species.
6. The vast **Deccan Peninsula,** with its tropical, dry deciduous forests, encompasses the Eastern Ghats and central plateau.
7. The fertile **Gangetic Plain** supports lush vegetation and diverse wildlife, including the Ganges River Dolphin. Northeast India, another biodiversity hotspot, is rich in tropical forests and rare species like the one-horned rhinoceros.
8. **North-east India,** known for its lush tropical forests and high biodiversity, is a region of significant ecological importance. It is home to rare and endangered species such as the One-horned Rhinoceros and the Assam Roofed Turtle, with conservation efforts focusing on protecting its unique habitats against threats like deforestation and habitat fragmentation.
9. Mangroves, sand beaches, and coral reefs are just a few examples of the diverse ecosystems that characterise **India's coastal regions,** which extend along the edge of the mainland and include the island nations of Andaman, Nicobar, and Lakshadweep. These areas are crucial for marine biodiversity, hosting species like the Olive Ridley Turtle, Dugongs, and a variety of coral species, making them significant for conservation and marine studies.

10. The island zones of **Andaman, Nicobar and Lakshadweep** offer unique ecosystems ranging from tropical rainforests to coral atolls, each with distinct marine life and endemic species.

This intricate mosaic of biogeographic zones showcases India's rich biodiversity, leading us to explore the unique characteristics and conservation challenges of the Trans-Himalayan Zone.

Zone No.	Zone Name	Zone Area Sq km	Percentage of India's land area
1.	Trans-Himalaya	184823	5.62
2.	Himalaya	210662	6.41
3.	Desert	215757	6.56
4.	Semi-Arid	545850	16.60
5.	Western Ghats	132606	4.03
6.	Deccan Peninsula	1380380	41.99
7.	Gangetic Plain	354782	10.79
8.	Coasts	82813	2.52
9.	North-east	171341	5.21
10.	Islands	8249	0.25
	Grand Total	**3287263**	**100.00**

The Trans-Himalayan Zone

- **Geographical Overview:** The Trans-Himalayan Region, lying immediately north of the Great Himalayas, includes the **cold deserts of Ladakh in Jammu and Kashmir, North Sikkim, and the Lahaul-Spiti areas of Himachal Pradesh.** The **Karakoram, Ladakh, Zaskar and Kailash** mountain ranges encircle it, which covers about **186,200 km2, or 5.6%** of India's total land area.
- **Vegetation and Flora:** Vegetation in this region is sparse, primarily comprising **dry alpine scrub.** Key genera include **Saxifraga, Draba, Ephedra, Kobresia and Carex,** which contribute to the region's unique botanical landscape.
- **Wildlife:** This area is pivotal for wildlife conservation, hosting the world's largest populations of **wild sheep and goats.** It is also the habitat for rare species such as the **Snow Leopard** and the migratory **Black-necked Crane,** making it a critically fragile ecosystem.

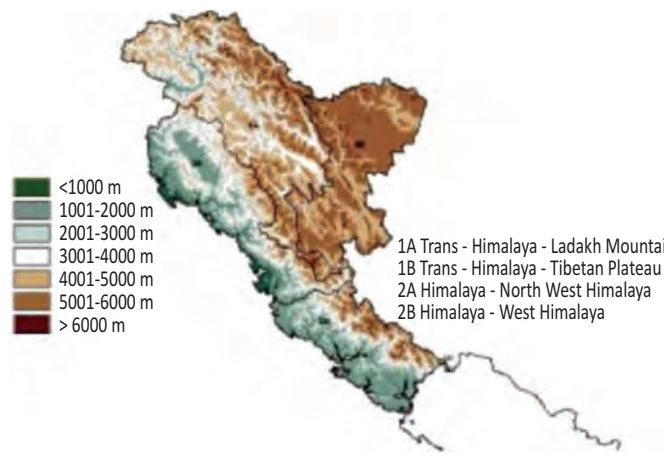


Fig. 5.21: Trans-Himalayan Region

Important Flora and Fauna From The Trans-Himalayan Zone

Species	IUCN Status	Characteristics	Threats	Conservation
Snow Leopard	Vulnerable	Large cat with a smoky-gray coat, pale green or grey eyes, and rosettes on the body and tail. Adapted to cold, mountainous environments.	Poaching, habitat loss and fragmentation, retaliation killings, Climate Change.	Project Snow Leopard (India), Global Snow Leopard, and Ecosystem Protection Programme.
Tibetan Antelope (Chiru)	Near Threatened	They are known for their underfur (shahtoosh), which is highly valued. Males have long, spiralled horns.	Poaching for fur, habitat degradation and Climate Change.	Protected under the Wildlife Protection Act of India; anti-poaching units to stop poaching
Wild Yak	Vulnerable	Large, with a dense undercoat, long hair, and massive horns. Adapted to high altitudes.	Habitat loss, competition with livestock, Climate change.	Protected areas in China and India; laws against hunting.
Black-necked Crane	Near Threatened	Large bird with a black neck and head, a white body, and a red crown patch. Breeds in high-altitude wetlands.	Habitat loss and degradation, Human disturbance and Climate Change.	Protected areas, breeding programmes and conservation education.
Himalayan Griffon	Near Threatened	Large vulture with a white body, dark wings, and a bare head.	Poisoning, decline in food availability, and electrocution from power lines.	Vulture conservation programs, bans on veterinary drugs harmful to vultures.

The Himalayan Zone

- **Geographical Overview:** Accounting for **6.4%** of India's total land area, the Himalayan Region stretches about **2,400 km from Kashmir to Arunachal Pradesh,** featuring some of the highest peaks in the world.

- **Vegetation and Flora:** The region is known for its remarkable diversity of vegetation, with over **8,000 species** of flowering plants, of which about **50%** are endemic. Tall conifers and broad-leaved species predominate in the western Himalayas, whereas the eastern Himalayas are renowned for their biodiversity, which includes over 85 species of **rhododendrons, bamboos, and orchids.**
- **Wildlife:** The Himalayan Region supports endangered bovid species such as the **Bharal, Ibex, Markhor and Takin.** Additionally, it provides sanctuary to other rare animals like the **Hangul and Musk Deer,** emphasising its significant role in biodiversity conservation and the necessity for ongoing protection efforts.

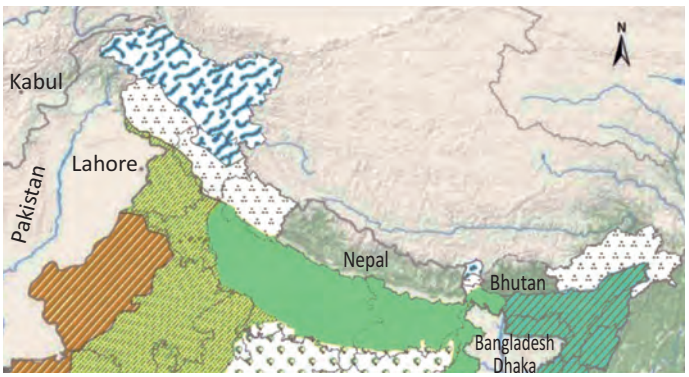


Fig. 5.22: Himalayan Zone

Important Flora and Fauna From The Himalayan Zone

Species	IUCN Status	Characteristics	Threats	Conservation
Red Panda	Endangered	Small mammal with reddish-brown fur, a long, shaggy tail, and a waddling gait. It eats mostly bamboo but is omnivorous.	Habitat loss, deforestation, poaching, and inbreeding depression.	Protected under national wildlife protection laws in their range countries; conservation programmes in India, Nepal, and China.
Himalayan Musk Deer	Endangered	A small deer with no antlers, has a musk gland that produces musk used in perfumes. Solitary and elusive.	Poaching for musk, habitat loss, and fragmentation.	Protected areas, anti-poaching efforts, and legal protection under CITES.
Monal Pheasant	Least Concern	Colourful bird with a metallic green head, crimson body, and long tail feathers. Known for its iridescent plumage.	Habitat destruction, hunting, and disturbance from tourism.	Habitat protection, hunting regulations, and awareness programmes.
Rhododendron	Varies by species	Large genus of shrubs and small trees, known for their large clusters of flowers. It widely varies in size and colour.	Habitat destruction, overharvesting, and climate change.	Conservation of habitats, specific species protection programmes, botanical gardens.
Himalayan Yew	Endangered	Slow-growing tree known for its medicinal properties, including the cancer drug taxol. Dark green needles, red berries.	Overharvesting for medicinal use, habitat loss, and deforestation.	Legal protection, cultivation programmes, and sustainable harvesting practices.
Himalayan Tahr	Near Threatened	A large ungulate with a thick reddish-brown to dark brown coat, males have a large mane. It inhabits rocky outcrops and grassy slopes in the Himalayas.	Habitat loss and fragmentation, competition with livestock, poaching.	Protected under the Wildlife Protection Act, 1972, in India; included in various protected areas across its range. Conservation efforts focus on habitat protection and anti-poaching measures.
Hangul (Kashmir Stag)	Critically Endangered	The Kashmiri hangul, also known as the Kashmir stag, is a subspecies of Central Asian red deer that is endemic to Kashmir and surrounding areas. It is the only surviving Asiatic member of the red deer family and the state animal of Jammu and Kashmir (UT).	Habitat destruction, poaching, predation, and competition with domestic livestock.	Project Hangul aimed to increase the population through habitat improvement, protection measures, and research. Included in Schedule I of the Wildlife Protection Act, 1972, is ensuring the highest level of protection.

Desert

- **Geographical Overview:** Covering **6.8%** of India's land surface, the Indian Desert Region is predominantly located in **Rajasthan, with extensions into Haryana, Punjab, and Gujarat.** The Aravalli hills border it to the north-east, it extends to the Rann of Kutch along the coast, and it reaches the Indus River's alluvial plains in the west and north-west, which have distinctive hillocks and sandy gravel plains.
- **Vegetation and Flora:** The region is noted for its rich vegetation, including dominant species such as **Acacia, Tecomella and Prosopis Cameraria,** and bushes like **Ziziphus, Capparis decidua and Calligonum polygonoides,** contributing to its diverse habitats and ecosystems.
- **Wildlife:** Home to endangered mammals like the **Wolf, Caracal, Desert Cat, Chinkara, Blackbuck, Chousingha, Nilgai and Gazelle,** the Indian Desert also supports avian species such as the **Houbara Bustard and the Great Indian Bustard,** along with eagles, harriers, falcons, kestrels, and vultures, making it a vital area for biodiversity.

Important Flora and Fauna From Desert Region

Species	IUCN Status	Characteristics	Threats	Conservation
Great Indian Bustard	Critically Endangered	Large ground bird, slow movement, known for its horizontal body and long, bare legs.	Habitat loss, poaching, and infrastructure development.	Project Great Indian Bustard in Rajasthan for habitat protection; included in Schedule I of the Wildlife Protection Act, 1972.
Chinkara	Least Concern	Medium-sized gazelles, with a light brown coat, can survive long periods without water.	Habitat loss, poaching, and predation by feral dogs.	Protected under the Wildlife Protection Act, 1972; conservation areas; and wildlife sanctuaries.
Blackbuck	Least Concern	Medium-sized antelope males have twisted horns and a dark brown to black coat.	Habitat loss, poaching, and overgrazing by livestock.	Protected under the Wildlife Protection Act, 1972; conservation reserves; and community conservation efforts.
Houbara Bustard	Vulnerable	Large, terrestrial birds living in arid climates. It comes in two distinct species: one in North Africa (Chlamydotis undulata) and the other in Asia (Chlamydotis macqueenii). The Asian Houbara Bustard migrates south to spend the winter in Pakistan, the Arabian Peninsula, and nearby Southwest Asia.	Poaching, unregulated hunting, and degradation of its natural habitat. Poaching, unregulated hunting, and degradation of its natural habitat.	International Fund for Houbara Conservation (IFHC) initiatives, include breeding programmes, habitat restoration, and strict regulation of hunting. Protected under various national laws in a range of countries.
Khejri (Prosopis cineraria)	Vulnerable	A medium-sized tree, sacred in many communities, provides fodder, fuel, and timber.	Overexploitation, agricultural expansion.	Social forestry programs; efforts to protect and plant in arid and semi-arid regions.

Semi-Arid Zone

- **Geographical Overview:** The semi-arid region, making up **16.6%** of India's geographical area, serves as a transitional zone between the arid Indian Desert and the lush Western Ghats. It is found across **Gujarat, Punjab, Haryana, and western Rajasthan,** characterized by erratic rainfall and high runoff. It is a transition zone between the desert and the dense forests of the Western Ghats.
- **Vegetation and Flora:** Thorn-scrub forests dominate the landscape, with species such as **Capparis decidua, Prosopis cineraria, and Flacourtia.** This vegetation supports a significant wildlife biomass, providing essential sustenance for the region's fauna.
- **Wildlife:** This region is a habitat for endangered species like the **Lion, Caracal, Jackal, and Wolf.** The **Sambar and Chital,** in particular, are found in the more wooded hills and moist valley areas, respectively, underscoring the semi-arid zone's critical role in biodiversity conservation.

Important Flora and Fauna From Semi-Arid Zone

Species	IUCN Status	Characteristics	Threats	Conservation
Indian Wolf	Least Concern	Smaller than its European cousin, with a reddish-gray coat, it inhabits open grasslands and scrublands.	Habitat loss, human-wildlife conflict, and poaching.	Protected under Schedule I of the Wildlife Protection Act, 1972, in India; conservation programmes; and protected areas.

Caracal	Least Concern	Medium-sized wild cat with distinctive tufted ears, known for its agility and ability to catch birds in flight.	Habitat loss, persecution, and trade.	Protected under the Wildlife Protection Act, 1972, in India; habitat conservation and anti-poaching efforts.
Lesser Florican	Critically Endangered	A small bustard, black and white plumage and a distinctive mating dance, found in grasslands.	Habitat loss, agricultural expansion, hunting.	Protected under the Wildlife Protection Act, 1972, in India; conservation programmes focus on grassland habitats.
Acacia	Not Listed/V	Large genus of shrubs and trees, known for their hardy nature and ability to thrive in dry conditions.	Overexploitation habitat loss, and invasive species.	Reforestation and sustainable management practices; some species are part of conservation projects.

Western Ghats

- **Geographical Overview:** Occupying **4.0%** of India's total geographical area, the Western Ghats stand as a monumental biogeographic zone, second only to the Himalayas in terms of floristic richness and diversity.
- **Vegetation and Flora:** This region is home to approximately **4,000 species** of flowering plants, with around **1,500 species** being endemic. The moist deciduous forests at lower elevations are notable for their valuable timber species, including the **Indian Rosewood (Dalbergia latifolia), KuhAsini/Blackz murdah (Terminalia crenulata), Indian kino tree (Pterocarpus marsupium), and Teak (Tectona grandis).**
- **Wildlife:** The Western Ghats are home to many unique animal species, including the **Nilgiri Langur (Presbutis johnii), the Lion-Tailed Macaque (Macaca silenus), the Grizzled Giant Squirrel (Ratufa macroura), and the Malabar Grey Hornbill (Ocyceros griseus).** This shows how important this area is for protecting biodiversity.

Important Flora and Fauna From Western Ghats

Species	IUCN Status	Characteristics	Threats	Conservation
Lion-tailed Macaque	Endangered	Small to medium-sized primate with a silver-white mane and a tail with a tuft at the end resembling a lion's. Lives in rainforests.	Habitat loss, fragmentation, and human encroachment.	Part of Schedule I of the Indian Wildlife (Protection) Act, 1972; included in various protected areas across the Western Ghats.
Nilgiri Tahr	Endangered	A stocky goat with short, coarse fur and a bristly mane. Males have a darker colour compared to females. Inhabits open montane grassland habitats.	Habitat loss, oaching, and competition with livestock.	Protected areas specifically for Tahr conservation, like Eravikulam National Park; part of Schedule I of the Wildlife Protection Act, 1972.
Indian Elephant	Endangered	Large mammal with grey skin and a trunk, known for its intelligence and complex social structure. Found in forested regions and grasslands.	Habitat loss, human-elephant conflict and poaching for ivory and other parts.	Project Elephant, initiated in 1992 to provide financial and technical support for elephant conservation,.
Malabar Pied Hornbill	Near Threatened	Large bird with a distinctive yellow and black hornbill, known for its large beak and casque. Prefers dense forests.	Habitat loss and fragmentation.	Protected under the Wildlife Protection Act, 1972; conservation efforts in protected areas.
Great Indian Hornbill	Vulnerable	Large bird with a prominent yellow and black casque on its bill. Known for its loud calls and deep, wing beats,. Found in dense forests.	Habitat loss, hunting, and trade.	Included in Schedule I of the Wildlife Protection Act, 1972; conservation and breeding programmes in various sanctuaries.
King Cobra	Vulnerable	The world's longest venomous snake, known for its hood and ability to "stand up". Prefers dense highland forests.	Habitat loss, poaching for skin and traditional medicine.	Protected under the Wildlife Protection Act, 1972; conservation programmes and awareness; campaigns to reduce human-snake conflict.
Neelakurinji (Strobilanthes kunthiana)	Near Threatened	A shrub that blooms once every 12 years, covering mountains in a blue-purple hue. Endemic to the Western Ghats.	Habitat loss, climate change and human encroachment.	Conservation areas established to protect blooming sites; awareness programmes for sustainable tourism.

Deccan Peninsula

- **Geographical Overview:** Constituting **42.0%** of India's total geographical area, the Deccan Plateau is India's richest biogeographic region. It is a semi-arid zone located in the **rain shadow area of the Western Ghats,** covering extensive zones in Madhya Pradesh, Maharashtra, and Odisha.
- **Vegetation and Flora:** The Deccan Plateau is characterised by **tropical thorn forests, tropical dry and moist deciduous forests, and degraded shrublands.** Notable species include **Teak (Tectona grandis), Axlewood (Anogeissus latifolia), Indian Frankincense (Boswellia serrata), and Bustard Teak (Butea monosperma).** The tropical moist deciduous forest includes species such as Kadam (Adina cardifolia), Satinwood/Buruta (Chloroxylon swietenia), and Coromandel ebony/Tendu (Diospyros melanoxylon).
- **Wildlife:** The region supports diverse fauna, including **Chital (Axis axis), Sambar (Rusa unicolor), Nilgai (Boselaphus tragocamelus), Chousingha (Tetracerus quadricornis), Barking Deer, Gaur (Bos gaurus), and Elephants (Elephas maximus)** in specific belts. Wild buffalo and swamp deer are found at the junction of Odisha, Madhya Pradesh, and Maharashtra, underscoring the plateau's importance for wildlife conservation.

Important Flora and Fauna From the Deccan Peninsula

Species	IUCN Status	Characteristics	Threats	Conservation
Indian Leopard	Vulnerable	Medium-sized big cat with a golden, spotted body, adaptable to various habitats, including forests, grasslands, and human-dominated areas.	Habitat loss, human-wildlife conflict, and poaching for its skin and other body parts.	Protected under Schedule I of the Wildlife Protection Act, 1972; conservation programmes; and protected areas.
Sloth Bear	Vulnerable	Nocturnal, insectivorous bear with long, shaggy fur and a distinctive white V on its chest. Prefers dry to moist forests and grasslands.	Habitat loss, human-wildlife conflict, poaching for bile, and other body parts.	Project Elephant (also benefits sloth bears by conserving their habitat); protected under the Wildlife Protection Act, 1972.
Peafowl (Peacock)	Least Concern	A large, colourful bird, the male has a spectacular tail of feathers. Found in forests, grasslands, and near human settlements.	Habitat loss, poaching for feathers, and human-wildlife conflict.	National bird of India, ensuring a high level of legal protection; conservation efforts in protected areas.
Teak	Endangered	A large deciduous tree is valued for its high-quality timber. Found in mixed hardwood forests.	Overexploitation, habitat conversion for agriculture.	Regulated harvesting; reforestation, and plantation programs; protected under various forest conservation laws.
Red Sandalwood	Endangered	Medium-sized tree known for its aromatic wood and oil, used in cosmetics, medicine and incense.	Overexploitation, illegal harvesting, and habitat loss.	CITES Appendix II; conservation and plantation programmes; regulated trade and harvesting policies.

Gangetic Plains

- **Geographical Overview:** The Gangetic Plain covers approximately **13%** of India's total geographical area, making it the largest unit of the great plains of India. It stretches from Delhi to Kolkata, encompassing the states of **Uttar Pradesh, Bihar and West Bengal.** Notably, the Gangetic Plain is referred to as the **food bowl of India**, providing food grains to millions due to its **flat topography suitable for agriculture** and the presence of **perennial rivers** that ensure year-round irrigation.
- **Vegetation and Flora:** Although cultivated plants have largely replaced the native vegetation in this area, the Terai regions at the foothills of the Himalayas still contain tall grasses like **Kangaroo Grass (Themeda), Saccharum and Phragmites, as well as trees like Shikakai, Neem, Mango, Mahua, Serpentine Wood and White Sandalwood.**
- **Wildlife:** Characteristic fauna of the Gangetic Plain includes the **Bengal Tiger, Rhino (Rhinoceros unicornis), Elephant (Elephas maximus), Buffalo (Bubalus bubalis), Swamp Deer (Rucervus duvaucelii), Hog Deer (Axis porcinus) and Hispid Hare (Caprolagus hispidus),** highlighting the region's biodiversity.

Important Flora and Fauna From the Gangetic Plains

Species	IUCN Status	Characteristics	Threats	Conservation
Bengal Tiger	Endangered	Iconic large cat with a striking orange and black striped coat, inhabiting a variety of habitats including grasslands, forests, and mangroves within the region.	Poaching for their fur and body parts, habitat loss due to deforestation, and human-wildlife conflict.	Project Tiger, initiated in 1973 to protect tiger habitats and increase their population; creation of tiger reserves.

Ganges River Dolphin	Endangered	Aquatic mammals are adapted to live in the murky waters of the Ganges, are characterised by a long snout and visible teeth, and rely on echolocation to navigate and hunt.	Pollution, accidental bycatch in fisheries, and habitat fragmentation due to dam and barrage construction.	The Ganges River Dolphin Conservation Programme; included in Schedule I of the Wildlife Protection Act, 1972, ensuring legal protection.
Sarus Crane	Vulnerable	The world's tallest flying bird, displaying a striking crimson head and upper neck with a grey body, is primarily found in open wetlands and agricultural fields.	Habitat destruction, human disturbance, and poisoning from the use of agricultural chemicals.	Protected under the Wildlife Protection Act, 1972; conservation efforts include habitat restoration and community engagement programmes.

North-East Region

- **Geographical Overview:** Occupying **5.2%** of India's total geographical area, the North-East Region serves as a crucial transition zone between the **Indian, Indo-Malayan, and Indo-Chinese** bio-geographical regions. It also marks the confluence of the Himalayan Mountains with Peninsular India, making it a unique area of ecological and geographical significance.
- **Vegetation and Flora:** The North-East Region showcases an exceptional variety of plant life, with a remarkable concentration of primitive flowering plants. It exhibits maximum diversity in species such as **orchids, bamboos, ferns, Musaceae (banana family), and Cucurbitaceae (gourd family),** underscoring its importance in the study and conservation of plant biodiversity.
- **Biodiversity:** This zone stands out for its rich biological diversity at the community, species and endemic levels. Approximately **50%** of India's total number of species are found here, including a significant portion in Arunachal Pradesh. The region is notable for housing some of the most ancient species of living angiosperms.

Important Flora and Fauna From the North-East Region

Species	IUCN Status	Characteristics	Threats	Conservation
One-horned Rhinoceros	Vulnerable	Large mammal with a single horn, thick grey skin, and known for its solitary behaviour. Inhabits the grasslands and forests, particularly in Assam.	Poaching for its horn, habitat loss due to agricultural expansion, and human-wildlife conflict.	Indian Rhino Vision 2020 includes increasing the population and expanding its habitat; protected areas like Kaziranga National Park.
White-winged Wood Duck	Endangered	Large duck with striking white wings and a preference for dense forest habitats near streams and ponds.	Habitat destruction, hunting and disturbances from human activity.	Protected areas and reserves; conservation breeding programmes; awareness campaigns to protect habitats.
Assam Roofed Turtle	Critically Endangered	A small to medium-sized turtle with a distinctively shaped shell, found in rivers and streams.	Habitat destruction, pollution and collection for the pet trade.	Legal protection under the Wildlife Protection Act, 1972; conservation breeding and habitat restoration projects.
Orchids	Varies according to species	A diverse group of flowering plants known for their beautiful flowers, with many species endemic to the region's forests.	Habitat loss due to deforestation, over collection for trade.	Orchid conservation and breeding programmes; protected areas to preserve natural habitats; awareness and education programmes.
Bamboo	Varies according to species	Fast-growing plants that form dense thickets, crucial for the ecosystem as they prevent soil erosion and provide material for construction and crafts.	Overexploitation, habitat conversion for agriculture and improper management.	Sustainable management practices; community-based conservation projects; promotion of bamboo as a renewable resource.

Coastal Region

- **Geographical Overview:** Occupying **2.5%** of India's total geographical area, the Coastal Region features sandy beaches, mangroves, mud flats, coral reefs, and marine angiosperm pastures, contributing significantly to India's ecological wealth and health. The coastline extends from Gujarat to Cape Comorin in the west, encompassing diverse ecosystems.
- **Vegetation and Flora:** This region is characterised by two major vegetation types: **mangrove forests and beach forests.**
  - **Beach forests:** They are home to species like the **Australian Pine Tree (Casuarina equisetifolia), Cashew Tree (Anacardium occidentale), and Indian Doomba Oiltree (Calophyllum inophyllum).** The Lakshadweep islands, consisting of **25 islets** of coral

origin, feature a unique reef lagoon system rich in biodiversity but have minimal natural vegetation due to the dense human population.

- **Mangrove Ecosystems: Rhizophora, Sonneratia, Heretiera, and Xylocarpus** are some of the genera that make up mangrove forests, which are found along deltas, estuaries, and backwaters. They are very important for protecting and maintaining coastal ecology.

Island Region

- **Geographical Overview:** The Island Region, comprising **0.3%** of India's total geographical area, includes the **Andaman and Nicobar** groups of islands in the Bay of Bengal, featuring **348** islands with unique bio-geographical characteristics.
- **Vegetation and Flora:** The dense vegetation on the islands is categorised into **littoral and inland types.**
  - **Littoral forests:** They have plants like the **Andaman Bulletwood (Manilkara), the Indian Doomba Oiltree (Calophyllum inophyllum), the Sea-Almond (Terminalia catappa), the Fish-Poison Tree (Barringtonia asiatica),** and mangroves like the Re -Mangrove (Rhizophora mucronata) and the Garjan (R. apiculata).
  - **Inland vegetation:** It is characterised by evergreen and deciduous forests, featuring economically important timber species like **East Indian Mahogany (Pterocarpus dalbergioides) and Frywood (Albizia lebbeck).**
- **Biodiversity:** These islands are hotspots of high endemism, housing some of India's most pristine evergreen forests and a diverse array of corals. Approximately **2,200 species** of higher plants are found here, including about **210 endemic species, of which 75 are trees,** underscoring the islands' significant ecological value.

Status of Biodiversity Loss in India

India is home to **four major biodiversity hotspots,** areas rich in species diversity and endemism yet facing severe habitat loss. The **'State of India's Environment Report', 2021** makes the following observations:

- **Endangered Species:** The **International Union for Conservation of Nature (IUCN)** monitors **1,212 animal** species in India, of which more than **12%** are classified as **endangered.** This includes a diverse group of **69 mammals, 23 reptiles and 56 amphibians.** The endangerment of these species underscores the pressing need for protective measures to preserve India's unique wildlife. The report reveals a staggering **loss of over 90% of the area under these hotspots,** with the **Indo-Burma** region being the worst affected**, losing 95%** of its vegetation area. This drastic reduction in natural habitats has also led to the extinction of **25 species** within these hotspots.
- **Forest Fires:** The incidence of forest fires presents another significant challenge to biodiversity conservation in India. The report notes an alarming number of 345,989 **forest fires** recorded from November 2020 to June 2021 highlighting an increase in such events across **16 states.** This trend is particularly concerning given the **record-breaking heat and surplus rainfall,** creating conditions conducive to the spread of fires.
- **Carbon Sequestration:** A decline in carbon retention services, or carbon sequestration, has been observed in **14 states or union territories.** Carbon sequestration is vital for mitigating global warming by capturing atmospheric carbon dioxide. The reduction in these natural services indicates a diminished capacity to combat climate change, emphasising the need for sustainable management practices.

The findings from the **'State of India's Environment in Figures', 2021** report illustrate the critical challenges facing India's biodiversity. The loss of biodiversity hotspots, the threat to endangered species, the rise in forest fires, and the decline in carbon sequestration services all signal a dire need for immediate and effective conservation strategies. Addressing these issues is imperative to safeguarding India's natural heritage and ensuring the long-term health of its ecosystems.

ISSUES LEADING TO BIODIVERSITY LOSS IN INDIA

India, as a **mega-biodiversity country,** faces significant challenges in conserving its rich biodiversity. The loss of biodiversity, threats to habitats and species, and the looming shadow of extinction are pressing issues that have far-reaching impacts on ecological balance, livelihoods, and cultural heritage. A combination of natural and anthropogenic factors is responsible for these difficulties. The following are the issues that are causing the loss of biodiversity in India:

- **Habitat Destruction:** The **conversion of forests and wetlands** into agricultural lands, urban areas and industrial sites has led to significant habitat loss. **Deforestation** for timber, mining activities and the construction of dams and roads have fragmented habitats, making it difficult for wildlife to survive and migrate.
- **Pollution: Water, air, and soil pollution** from industrial waste, agricultural runoff, and industrial runoff have degraded natural habitats. **Pollution** not only affects species directly but also alters the nutrient cycles and ecological balance of habitats.
- **Climate Change:** Climate change poses a significant threat to India's biodiversity. **Rising temperatures, changing rainfall patterns, and extreme weather events** affect the distribution and survival of many species. The melting of Himalayan glaciers and rising sea levels also threaten coastal and mountain ecosystems.

- **Overexploitation:** The overexploitation of natural resources, such as **overfishing, hunting, and poaching,** has led to the decline of numerous species. The illegal wildlife trade, particularly of species like tigers, elephants, and rhinos, has pushed many animals to the brink of extinction.
- **Invasive Species:** The **introduction of non-native species has disrupted local ecosystems,** leading to the decline of indigenous species. Invasive species often compete with native species for resources, leading to a loss of biodiversity.

To address biodiversity loss in India, a multi-faceted approach is required, including scientific research, community participation, policy reform, and international cooperation. The conservation of India's biodiversity is critical not only for preserving its natural history but also for maintaining ecological sustainability, food security, and the well-being of future generations.

IGNITE YOUR MIND

The Culprits Revealed:

Biodiversity is facing a supervillain – a decline at an alarming rate! Can you guess who the culprits are? Unmask the primary causes of biodiversity loss and discover the potential consequences for the future of our planet.

Impact of Climate Change on India's Biodiversity

Climate change has a significant and multifaceted impact on India's biodiversity, affecting the country's diverse bio-geographical regions in a number of ways:

- **Changes in Species Distribution:** Climate change has led to shifts in the geographic ranges of various species as they adapt to changing conditions. For instance, some bird species have moved to **higher elevations to escape rising temperatures,** while others have sought cooler habitats.
  - **Example:** Bird species such as the **Black-throated Thrush and the Siberian Crane,** which migrate to India during winter, have shown changes in migration timing. These birds are arriving earlier or staying longer, likely in response to warmer temperatures which affects their breeding and feeding grounds.
- **Alterations in Climate Patterns:** The timing of seasonal events, such as **breeding, migration and flowering,** has been affected. Migratory bird species, for example, are arriving earlier in the spring, and some plants are flowering sooner than usual.
  - **Example:** Species like the **Snow Leopard in the Himalayas** face habitat shifts due to rising temperatures. The snow line is retreating to higher elevations, reducing their habitat and forcing them into smaller, fragmented areas, which can lead to increased human-wildlife conflicts and reduced genetic diversity.
- **Habitat Loss:** Increased temperatures have rendered some habitats unsuitable for species that were once **adapted to specific temperature and rainfall conditions,** leading to habitat loss and range contractions.
  - **Example:** The **coral reefs** around these islands have experienced severe **bleaching** events due to increased sea temperatures. Coral bleaching has an impact on the fish species that use these reefs for shelter and food, as well as the biodiversity they support.
- **Increased Biodiversity Extinction Risk:** Climate change exacerbates existing threats to biodiversity, such as habitat **destruction and fragmentation,** heightening the risk of extinction for many species.
  - **Example: Amphibian species in the Western Ghats,** for example, face an increased risk of extinction due to climate change.
- **Altered Ecosystem Services:** Climate change may have an impact on the provision of crucial ecosystem services like **water availability, pollination, and pest control.** This has significant implications for human communities that rely on these services for their livelihoods.
  - **Example:** An example of altered ecosystem services due to climate change in India is the impact on water availability in the **Himalayan region.**

These consequences highlight the critical need for integrated conservation strategies that address biodiversity preservation and climate change mitigation in order to protect India's rich natural heritage and people's well-being.

CONCLUSION

India's status as a **megadiverse country** entails a tremendous duty to safeguard and preserve its natural heritage. The issues of **habitat loss, climate change, pollution, overexploitation, and invasive species** pose severe threats to the country's biodiversity. However, India can overcome these difficulties by combining strong legislative frameworks, community engagement, scientific research, and international cooperation. Protecting biodiversity hotspots, implementing sustainable practices, and creating awareness about the necessity of conservation are critical measures towards sustaining India's environmental balance. **Biodiversity conservation** is important more than just conserving plants and animals; it is also about safeguarding humanity's long-term survival. As guardians of one of the planet's most diversified arrays of life, India has both the ability and responsibility to lead global biodiversity conservation efforts.

Biodiversity Conservation and Strategy

6

INTRODUCTION

Biodiversity, the variety of life on Earth, is a cornerstone of our planet's health and resilience. It encompasses the rich tapestry of ecosystems, species, and genetic diversity that collectively sustains life. However, in the face of human activities, climate change, and habitat destruction, biodiversity is under threat. This chapter explores the importance of biodiversity conservation, the challenges we face, and the strategies employed to safeguard the intricate web of life.

NEED OF BIODIVERSITY CONSERVATION

❑ **Ecological Balance and Ecosystem Services:**

- Biodiversity underpins the delicate balance of natural ecosystems, ensuring clean air and water, fertile soil, pollination, and natural pest control. These "ecosystem services" are essential for human well-being, food security, and overall environmental health.
  - ❒ The Supreme Court in the Subhash Kumar vs State of Bihar case held that the right to enjoy pollution-free water and air is an essential part of Fundamental Right to life under Article 21.
  - ❒ Furthermore, Article 48(a) of the Constitution states that the state should protect and improve the environment, forests, and wildlife.
- Loss of biodiversity disrupts these vital services, leading to issues like water scarcity, soil erosion, and declining agricultural productivity.
  - ❒ Forests act as natural filters and purifiers of water, and also help in preventing soil erosion and landslides.
  - ❒ Wetlands and mangroves act as natural buffers and protectors against floods, storms, and coastal erosion

❑ **Economic Benefits:**

- India's rich biodiversity offers immense economic potential through various sectors like:
  - ❒ **Tourism:** Diverse ecosystems and unique wildlife attract tourists, generating revenue and supporting local livelihoods.
    - ◊ India also has many biodiversity hotspots, such as the Western Ghats, the Himalayas, and the Andaman and Nicobar Islands, which attract millions of tourists every year.
  - ❒ **Natural resources:** Medicinal plants, timber, and various non-timber forest products provide valuable resources for various industries.
    - ◊ India also has a rich diversity of medicinal plants, which are used in traditional systems of medicine, such as Ayurveda, Unani, and Siddha.
    - ◊ According to the Secretariat of Convention on Biological Diversity (SCBD), the estimated economic potential of biodiversity in the pharmaceutical sector is about $640 billion of which 25-50 per cent is derived directly from biological resources, globally.
  - ❒ **Bioprospecting:** Exploring the potential of natural organisms for new drugs, materials, and agricultural applications can lead to significant economic benefits.

❑ **Climate Change Mitigation:**

- Healthy ecosystems with diverse vegetation play a crucial role in absorbing carbon dioxide, a major greenhouse gas contributing to climate change.
- Conserving biodiversity helps mitigate climate change by maintaining natural carbon sinks and promoting ecological resilience.

❑ **Cultural Significance:**

- India's diverse communities have traditionally co-existed with nature, developing deep cultural and spiritual connections with their surrounding ecosystems.
  - ❒ India has a rich heritage of biodiversity-related festivals, rituals, art, literature, and folklore, which reflect the deep connection between people and nature.
- Preserving biodiversity safeguards these cultural values and traditions, ensuring their continuity for future generations.

❑ **Ethical Responsibility:**

- We have a moral obligation to protect the natural world and its diverse inhabitants for their intrinsic value, not just for utilitarian purposes.
  - ❒ Fundamental Duties under Article **51A** of the Constitution provides for the protection of the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures.

- Conserving biodiversity ensures the survival of countless species and maintains the intricate web of life on which all living beings depend.

IGNITE YOUR MIND

A World in Crisis: Understanding the Urgent Need for Conservation

Imagine a silent forest, devoid of the calls of birds and the rustling of leaves. This is the potential future if we fail to act. Why is **biodiversity conservation** so crucial, and what are the consequences of inaction?

Threatened Species

An endangered species is one that faces a high risk of extinction in the near future, either globally or within a specific geographical area.

Causes of Endangerment:

- **Habitat Loss:** Destruction and fragmentation of natural habitats due to factors like deforestation, urbanization, and agricultural expansion.
- **Poaching:** Illegal hunting and capturing of animals for trade, traditional medicine, or other purposes.
- **Invasive Species:** Introduction of non-native species that outcompete or prey upon native species, disrupting ecosystems. E.g. Prosopis juliflora, introduced to India for afforestation and soil conservation, has negatively impacted biodiversity by outcompeting native vegetation, altering soil composition, and reducing water availability.
- **Pollution:** Environmental contamination affecting water, air, and soil quality, impacting the health of species.
- **Climate Change:** Altered weather patterns, temperature changes, and habitat shifts affecting species' survival.

Species in India that are on the verge of extinction

- Kolar Leaf-nosed Large bat-like rock rat
- Namdapha-The Squirrel That Can Fly
- Nicobar Hangul, also known as the Chinese Pangolin and Jenkin's Shrew
- Andaman White-toothed Shrew
- Pygmy Hog
- Malabar Civet
- Monitor lizard

What is a Red Data Book?

- The Red Data Book is a book that contains a list of all the endangered and vulnerable species. All threatened species of plants, fungi animals, subspecies, varieties (plants only) and subpopulations can be assessed on the Red List.
- It excludes following from the Red List; Hybrid species, domesticated taxa and micro organisms.
- The International Union for Conservation of Nature (IUCN) is involved in maintaining the Red data book. IUCN, which started back in the year 1948, and till now, reason : extreme statement.
- It helps in identifying species that are close to extinction and gives an opportunity to conserve them. These species are then transferred to the National Park and Wildlife Sanctuary.

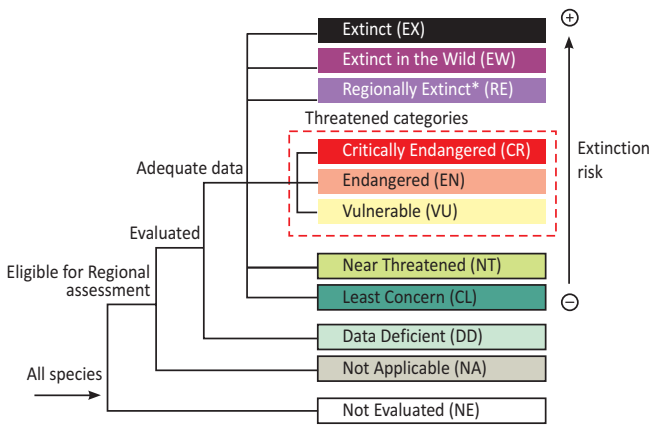


Fig. 6.1: Red List Categories of Species

As mentioned above, the IUCN has recognized **Nine** Red List Categories of species, which are defined as follows:

1. **Extinct:**

   A taxon is presumed extinct when exhaustive surveys fail to record an individual throughout its habitat and historic range. Currently, there are more than 157,100 species on The IUCN Red List, with more than 44,000 species threatened with extinction.

   Examples: Indian aurochs, Asian straight-tusked elephant.

2. **Extinct in the wild:**

   A taxon is presumed extinct in the wild
   - when exhaustive surveys fail to record an individual throughout its habitat and historic range and;
   - It is known only to survive in cultivation, in captivity or as a naturalised population well outside the past range.
   - **Example:** Golden Skiffia, Captain Cook's Bean Snail

3. **Critically Endangered:**

   A taxon is presumed Critically endangered if:
   - Reduction in population (> 90% over the last 10 years),
   - Population size < 50 mature individuals — not applied strictly. Many CR species have populations > 50),
   - Probability of extinction in wild in at least 50% in 10 years.
   - It is therefore considered to be facing extremely high risk of extinction in the wild.
   - **Example:** Pygmy Hog, Namdapha Flying Squirrel, Pink Headed Duck, Himalayan quail, Gharial, Four-toed river terrapin, Gliding Frog, Siberian Crane.

4. Endangered:

A taxon is presumed Endangered if:

- Reduction in population size (70% over the last 10 years),
- Population size estimated to number fewer than 250 mature individuals,
- Quantitative analysis showing the probability of extinction in wild by at least 20% within 20 years.
- It is therefore considered to be facing a very high risk of extinction in the wild.
- **Example:** Bengal Tiger, Asiatic Lion, Lion-tailed Macaque **(endemic to the Western Ghats)**, Western Hoolock Gibbon.

5. Vulnerable

A taxon is presumed Vulnerable if:

- Reduction in population (> 50% over the last 10 years),
- Population size estimated to number fewer than 10,000 mature individuals,
- Probability of extinction in wild is at least 10% within 100 years, and
- It is therefore considered to be facing a high risk of extinction in the wild.
- **Example:** One-horned Rhinoceros, Snow Leopard, Nilgiri Langur, Yak, Olive Ridley Turtle.

6. Near Threatened

- When it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
- **Example:** Tibetan Macaque, Tufted Deer, Marbled Cat, Tiger Shark

7. Least Concern (LC)

- When it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are often included in this category.
- **Example:** Small Giant Clam, Tridacna squamosa, Tabernaemontana gamblei.

8. Data Deficient

- A taxon is Data Deficient when there is inadequate information to make a direct or indirect assessment of its risk of extinction.
- **Example:** Brick Seamot, Andaman Cone, Giant Herring, Mahseer.

9. Not Evaluated

A taxon is Not Evaluated when it has not yet been assessed against the above criteria.

Latest Red List Update

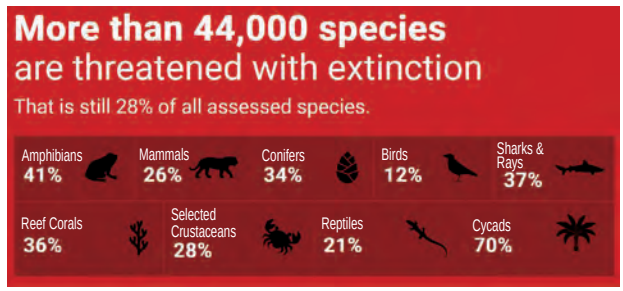


Fig. 6.2: Threatened Species

❑ Climate Change Threat:

- The update emphasizes the rising threat of climate change to various species.
- Examples include the Atlantic salmon and green turtles facing increased danger due to climate impacts.
- Urgent action to combat climate change is deemed crucial to prevent further species decline.

❑ Freshwater Fish Crisis:

- For the first time, a comprehensive assessment of global freshwater fish reveals a concerning scenario.
- A quarter of all assessed freshwater fish species are at risk of extinction.
- Climate change, pollution, overfishing, and invasive species are major contributors to this decline.

❑ Atlantic Salmon Decline:

- The Atlantic salmon population has witnessed a significant drop (23%) between 2006 and 2020.
- This decline has led to a change in their conservation status from Least Concern to Near Threatened.

❑ Green Turtle Vulnerability:

- Green turtle populations in specific regions (Central South Pacific and East Pacific) are now classified as Endangered and Vulnerable, respectively.
- Climate change impacts their entire life cycle, affecting hatching success and food availability.
- Green sea turtle is primarily herbivorous.

❑ Mahogany Tree Endangered:

- The big-leaf mahogany, a valuable timber tree, has shifted from Vulnerable to Endangered due to unsustainable harvesting, habitat loss, and illegal logging, leading to a 60% decline over the past 180 years.

❑ Conservation Success Stories:

- The scimitar-horned oryx, once declared Extinct in the Wild, has been successfully reintroduced in Chad and is now classified as Endangered.
- Saiga antelope populations have shown significant improvement, moving from Critically Endangered to Near Threatened due to effective conservation efforts.

Strategies for Conservation

Biodiversity conservation means taking care of different plants and animals, making sure we use them in a way that lasts a long time. The main goals are to keep different kinds of species safe, use them in a way that doesn't harm them or their homes, and make sure the natural systems that support life keep working well.

Biodiversity conservation

In-Situ Conservation	Ex-Situ Conservation
1. Protected areas	1. Seed banks, Gene banks
• National Parks	2. Long term captive breeding
• Sanctuaries	3. Animal translocations
• Biosphere reserves	4. Tissue culture banks
2. Sacred forests and lakes	5. Cryopreservation of gametes and embryos
	6. Botanical gardens
	7. Zoological gardens (Zoos)

In-Situ Conservation

In-situ conservation, also known as on-site conservation, refers to the protection of species and ecosystems within their natural habitats. This approach aims to address the root causes of biodiversity loss by directly managing and safeguarding the environments where plants and animals naturally thrive.

Key objectives of in-situ conservation:

- Habitat protection: Establishing protected areas like national parks, wildlife sanctuaries, biosphere reserves, reserved forests and protected forests.
- Habitat restoration and management: Rehabilitating degraded habitats and managing activities within protected areas.
- Species management: Controlling invasive species, mitigating disease outbreaks, and managing population dynamics of threatened species.
- Community engagement: Working with local communities to empower them to sustainably manage their resources and biodiversity.

Benefits of in-situ Conservation

- **Preserves biodiversity:** Protects the full range of species and their interactions within an ecosystem.
- **Maintains ecosystem services:** Ensures natural processes like pollination, water purification, and climate regulation continue.
- **Supports sustainable livelihoods:** Promotes sustainable resource use by local communities.
- **Provides ecological resilience:** Helps ecosystems adapt to changing environmental conditions.

Examples of In-Situ Conservation Practices

- **Biosphere reserves:** These are large areas of land, often exceeding 5000 sq. km, that include one or more protected areas and surrounding buffer zones. Biosphere reserves aim to conserve biodiversity and promote sustainable development, research, and education.
  - For example, the Nilgiri Biosphere Reserve in India covers parts of three states and contains several national parks and wildlife sanctuaries.
- **National parks:** These are protected areas where wildlife and the environment are conserved. National parks prohibit or regulate human activities, such as hunting, logging, mining, and tourism, that may harm the natural resources and biodiversity.
  - For example, the Jim Corbett National Park in India is the oldest national park in Asia and hosts a rich diversity of flora and fauna, including the endangered Bengal tiger.
- **Wildlife sanctuaries:** These are protected areas where specific species of animals or plants are conserved. Wildlife sanctuaries allow limited human activities, such as research, education, and tourism, that do not disturb the wildlife.
  - For example, the Kaziranga National Park in India is a wildlife sanctuary that is home to the largest population of the one-horned rhinoceros in the world.

Challenges of In-Situ Conservation

- Balancing conservation with human needs: Addressing conflicts between resource use and conservation goals.
- Securing funding: Sustaining long-term conservation efforts requires financial support.
- Addressing climate change: Mitigating and adapting to the impacts of climate change on ecosystems.

Ex -Situ Conservation

Ex-situ conservation, meaning **"off-site" conservation,** refers to the protection of species and genetic material outside their natural habitats. This typically involves keeping individuals in controlled environments like zoos, botanical gardens, gene banks, seed banks and **horticultural & recreational gardens.**

Key Objectives of Ex-Situ Conservation

- Preserving critically endangered species: Preventing extinction by maintaining captive populations.
- Reintroduction programs: Restoring species to their native habitat once threats are managed.
- Education and awareness: Inspiring public interest and support for conservation through public displays and educational programs.
- Genetic diversity management: Collecting and storing genetic material to prevent loss of genetic variability.

Benefits of Ex-Situ Conservation

- **Immediate action:** Can quickly rescue critically endangered species from imminent threats.

- **Controlled environment:** Provides protection from habitat loss, poaching, and natural disasters.
- **Research and breeding:** Facilitates studies on reproduction, disease resistance, and reintroduction feasibility.
- **Education and fundraising:** Generates public interest and support for conservation efforts.

Examples of Ex-Situ Conservation Practices

- **Zoos:** Breeding programs for endangered species like pandas and California condors.
- **Botanical gardens:** Preserving rare and endangered plant species, like cycads and cacti.
- **Gene banks:** Storing seeds and tissues of diverse plant and animal species for future use.
- **Aquariums:** Maintaining populations of threatened fish and aquatic species, like coral reefs.
- **Frozen zoos:** Cryopreserving sperm, eggs, or embryos for future reintroduction attempts.

Challenges of Ex-Situ Conservation

- **High costs:** Maintaining captive populations and facilities requires significant financial resources.
- **Ethical considerations:** Concerns about animal welfare and potential loss of natural behaviors in captivity.
- **Reintroduction difficulties:** Adapting individuals back to their natural habitats can be challenging.
- **Limited scope:** Not all species are suitable for ex-situ conservation due to complex ecological needs.

The need for biodiversity conservation is not just a scientific or environmental concern; it is a fundamental aspect of ensuring a sustainable and harmonious future for humanity and the planet. Through concerted efforts, policies, and individual actions, we can strive to protect and nurture the incredible diversity of life that makes Earth a unique and thriving home for all living beings.

NATIONAL BIODIVERSITY CONSERVATION FRAMEWORK

India is one of the 17 megadiverse countries in the world, boasting a rich tapestry of ecosystems, from the snow-capped Himalayas in the north to the tropical rainforests of the south. This incredible biodiversity is essential for the well-being of the planet and its people, providing food, clean water, air, and countless other benefits.

Constitutional Mandate

- **Article 48A:** The State shall endeavor to protect and improve the environment and to safeguard the forests and wildlife of the country. This Article was added by the 42nd Amendment, 1976 and places an obligation on the State to protect the environment and wildlife.
  - Moreover, the Supreme Court, in its judgment in Animal Welfare Board of India vs A. Nagaraja & Ors (2014), had declared, "Every species has a right to life and security, subject to the law of the land, which includes depriving its life out of human necessity."
- **Article 51A(g):** It states that it shall be the **Fundamental Duty** of every citizen to protect and improve the natural environment including forests, lakes, rivers and wildlife, and to have compassion for living creatures.
- **Article 21:** It protects the right to life as a **Fundamental Right,** which includes the right to a clean and healthy environment.
- **Article 246:** It places forests and protection of wild animals in the concurrent list, which enables both the central and state governments to enact laws on these subjects.

India has undertaken numerous efforts across various levels to conserve its rich biodiversity. Here are some key initiatives:

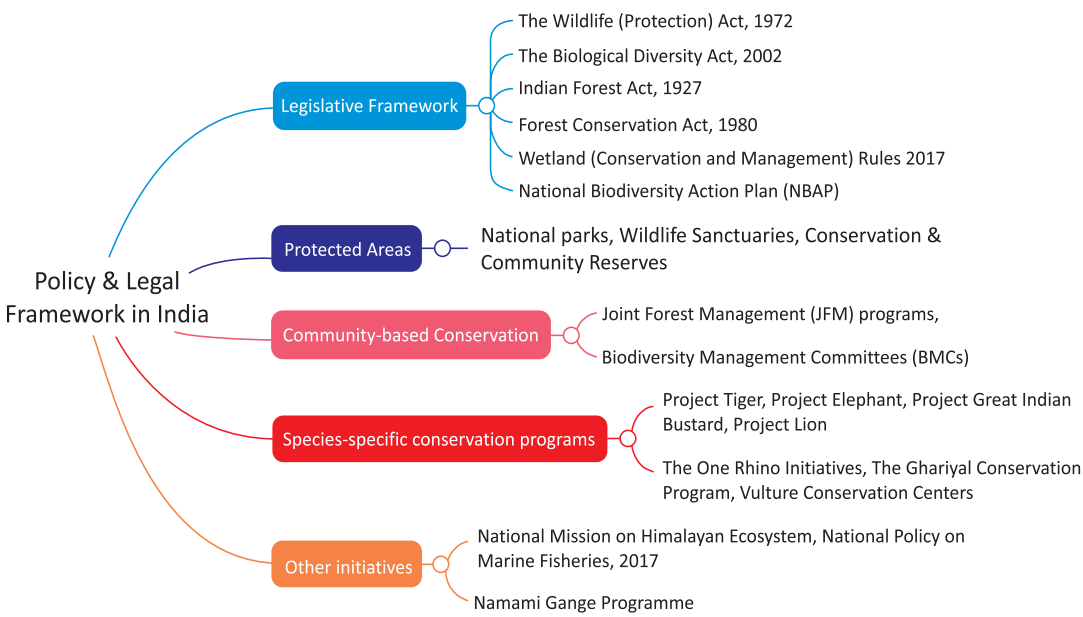

Policy & Legal Framework in India
Legislative Framework
The Wildlife (Protection) Act, 1972
The Biological Diversity Act, 2002
Indian Forest Act, 1927
Forest Conservation Act, 1980
Wetland (Conservation and Management) Rules 2017
National Biodiversity Action Plan (NBAP)
Protected Areas
National parks, Wildlife Sanctuaries, Conservation & Community Reserves
Community-based Conservation
Joint Forest Management (JFM) programs,
Biodiversity Management Committees (BMCs)
Species-specific conservation programs
Project Tiger, Project Elephant, Project Great Indian Bustard, Project Lion
The One Rhino Initiatives, The Ghariyal Conservation Program, Vulture Conservation Centers
Other initiatives
National Mission on Himalayan Ecosystem, National Policy on Marine Fisheries, 2017
Namami Gange Programme

Fig. 6.3: Policy & Legal Framework in India

Legislative Framework and Policy Framework

India boasts rich and diverse ecosystems, making it a global biodiversity hotspot. Recognizing this significance, the country has established a robust policy and legal framework to conserve and sustainably manage its biological resources.

The Wildlife (Protection) Act, 1972

The Wildlife (Protection) Act, 1972 is an Act of the Parliament of India enacted for the protection of India's diverse flora and fauna. According to Section 39 of Wild Life (Protection) Act, 1972, Every Wild Animal shall be the property of the Government.

- **Protected Areas:** Empowers the establishment of national parks, sanctuaries, and conservation reserves to provide safe havens for wildlife.
- **Poaching Regulation:** Bans poaching except for specific circumstances under permits, significantly curbing wildlife exploitation. The Act provides for equal protection for wild animals irrespective of where they are found.
- **Commerce Control:** Regulates commerce in wildlife and their derivatives to prevent illegal activities and exploitation.
- **Institutional Framework:** Establishes authorities like the National Tiger Conservation Authority for specialized conservation efforts.

Impact on Biodiversity

- **Reduced Poaching:** The Act has significantly curbed uncontrolled poaching, allowing animal populations to recover.
- **Habitat Protection:** Creation of protected areas safeguards critical habitats, ensuring the survival of various species.
- **Species Conservation:** Specialized efforts on specific endangered species like tigers have shown positive results.
- **Biodiversity Enhancement:** By protecting various species and their habitats, the Act contributes to maintaining a healthy and diverse ecosystem.

IGNITE YOUR MIND

Beyond Paper Tigers: Building a Robust Legal Framework for Conservation

Effective conservation requires more than just good intentions. Explore the intricate web of policies and legislative measures, like the Wildlife Protection Act, that form the backbone of India's conservation efforts. If you were a policymaker, what innovative regulations could you implement to strengthen these efforts and ensure the future of our rich biodiversity?

Biological Diversity Act 2002

The Biological Diversity Act (BDA) of 2002 is a landmark law in India that aims to conserve biological diversity, ensure its sustainable use, and facilitate fair and equitable sharing of benefits derived from its use. It protects India's rich biodiversity and enables its sustainable management for future generations.

Indian Forest Act, 1927

- The Act regulates activities like felling trees, grazing, and collection of non-timber forest products. This can help control deforestation and overexploitation of resources, indirectly benefiting wildlife by preserving their habitat and food sources.
- Recent amendment to the Act permits felling and transit of bamboo grown in non-forest areas. However, bamboo grown on forest lands would continue to be classified as a tree and thus beyond felling.

Forest Offences: The Act defines and penalizes forest offences like poaching, illegal logging, and setting fires. This helps deter activities that directly harm wildlife.

Degree of protection: Reserved forests > Protected forests > Village forests

Forest Conservation Act, 1980

The Forest Conservation Act (FCA) of 1980, enacted by the Indian Parliament, is a key legislation for wildlife conservation, even though it mainly focuses on forest protection. The FCA contributes to wildlife conservation in the following ways:

Indirect Protection:

- **Habitat Preservation:** The FCA prevents the deforestation and conversion of forest land for non-forest purposes, thereby preserving vital wildlife habitats. These habitats provide animals with food, shelter, and breeding sites, which are crucial for their survival.
- **Biodiversity Maintenance:** Forests are home to a variety of plants and animals, many of which are wildlife species. The FCA indirectly protects this biodiversity by promoting forest conservation, which maintains the ecological balance and the interdependence of different species.
- **Corridor Protection:** Forests often serve as corridors that link fragmented habitats and enable animals to move freely for mating, feeding, and avoiding threats. The FCA helps preserve these important corridors, which enhance gene flow and prevent population.

National Biodiversity Action Plan

A National Biodiversity Action Plan (NBAP) is a comprehensive document outlining a country's strategy and specific actions for conserving and sustainably using its biological diversity. It serves as a crucial tool for fulfilling the commitments made under the Convention on Biological Diversity (CBD).

Purpose:

- Addresses threats to biodiversity and promotes its conservation and sustainable use.
- Aligns with the goals and objectives set by the CBD.
- Integrates biodiversity considerations into relevant national policies and programs.

Components:

- **National Biodiversity Strategy:** Describes the country's vision for biodiversity and the broad policy measures to achieve it.
- **Action Plan:** Comprises concrete actions to be taken to implement the strategy, addressing various aspects like:
  - **Species and habitat conservation:** Protecting endangered species and their habitats.
  - **Sustainable use of biodiversity:** Utilizing resources in a way that maintains their long-term viability.
  - **Public awareness and education:** Raising public understanding and promoting responsible behavior towards biodiversity.
  - **Institutional framework and capacity building:** Strengthening institutions and building expertise for effective implementation.

National Environmental Policy, 2006

It ensures coherence of purpose of conservation and enhancement of environment in all sectoral policies. It acknowledges and commits action on international environmental agreements to which India is a Party in conformity with India's commitments.

Its major objectives are as follows:

- To protect and conserve critical ecological systems and resources, and invaluable natural and man-made heritage, which are essential for life-support, livelihoods, economic growth, and a broad conception of human well-being.
- Intra-generational Equity.
- Inter-generational Equity.
- Integration of Environmental Concerns in Economic and Social Development.
- Efficiency in Environmental Resource Use.
- Environmental Governance: To apply the principles of good governance (transparency, rationality, accountability, reduction in time and costs, participation, and regulatory independence) to the management and regulation of use of environmental resources.
- Enhancement of Resources for Environmental Conservation: To ensure higher resource flows, comprising finance, technology, management skills, traditional knowledge, and social capital, for environmental conservation.

Key principles of the policy are:

- Human Beings are at the Centre of Sustainable Development Concerns.
- The Right to Development must be fulfilled.
- Environmental Protection is an Integral part of the Development Process.
- The Precautionary Approach.
- Economic Efficiency.
- Entities with "Incomparable" Values: Significant risks to human health, life, and environmental life-support systems, besides certain other unique natural and man-made entities, which may impact the well-being, broadly conceived, of large numbers of persons, may be considered as "Incomparable" in that individuals or societies would not accept these risks for compensation in money or conventional goods and services.
- **Equity:** The cardinal principle of equity or justice requires that human beings cannot be treated differently based on irrelevant differences between them. Equity norms must be distinguished according to context, i.e. "procedural equity", relating to fair rules for allocation of entitlements and obligations, and "end-result equity".
- **Legal Liability:** The present environmental redressal mechanism is predominantly based on doctrines of criminal liability, which have not proved sufficiently effective, and need to be supplemented.
- **Public Trust Doctrine:** The State is not an absolute owner, but a trustee of all natural resources, which are by nature meant for public use and enjoyment, subject to reasonable conditions, necessary to protect the legitimate interest of a large number of people, or for matters of strategic national interest.
- Decentralization in environmental governance.
- **Integration:** Integration refers to the inclusion of environmental considerations in sectoral policy making, the integration of the social and natural sciences in environment related policy research, and the strengthening of relevant linkages among various agencies at the Central, State, and Local Self-Government levels, charged with the implementation of environmental policies.
- **Environmental Standard Setting:** Environmental standards must reflect the economic and social development situation in which they apply.
- **Preventive Action:** It is preferable to prevent environmental damage from occurring in the first place.
- **Environmental Offsetting:** There is a general obligation to protect threatened or endangered species and natural systems that are of special importance to sustaining life, providing livelihoods, or general well-being.

National Policy on Marine Fisheries, 2017

The overarching goal of NPMF, 2017 is to ensure the health and ecological integrity of the marine living resources of India's EEZ (Exclusive Economic Zones) for the benefit of present and future generations of the nation. Its goals include:

- Sustainable development of fisheries for socio-economic uplift of fishers.
- Management of fisheries on the principle of subsidiarity and partnership and gender justice.
- Harvesting and management based on precautionary approach to secure intergenerational equity.
- Application of "Public trust doctrine in management while keeping fishers at the core".
- Mainstreaming biodiversity conservation in harvesting and production processes and management plans by adopting an ecosystem approach to management.
- Mainstreaming conservation of Ecologically and Biologically Significant Areas (EBSAs) and Vulnerable Marine Ecosystems (VMEs), protection of iconic and endangered and threatened species.

Note: for detailed information about structure of the above legislations and other Environment related laws, refer Chapter 15.

Institutional Framework

Botanical Survey of India (BSI)

The Botanical Survey of India (BSI) is a premier organization dedicated to the study and conservation of India's plant life. Established in 1890, it plays a crucial role in understanding and protecting the country's rich botanical diversity.

Key Roles and Responsibilities:

- **Exploring and documenting India's flora:** BSI scientists conduct expeditions to various regions, collecting and identifying plant species. They maintain extensive herbarium collections, housing millions of preserved plant specimens for research and reference.
- **Botanical research:** BSI conducts research on various aspects of plant life, including taxonomy, ecology, conservation, and ethnobotany. They publish their findings in scientific journals and contribute to the global understanding of plant diversity.
- **Conservation efforts:** BSI works to conserve threatened plant species and their habitats. They identify and manage protected areas, conduct awareness programs, and collaborate with other stakeholders to promote sustainable plant use.
- **Providing information and expertise:** BSI serves as a valuable resource for government agencies, researchers, students, and the general public. They offer a range of services, including plant identification, training programs, and access to their vast data and knowledge base.

Structure and Organization:

- The BSI is headquartered in Kolkata, with 11 regional centers across India.
- It is governed by a Governing Council chaired by the Secretary of the Ministry of Environment, Forest and Climate Change.
- The organization employs a team of scientists, taxonomists, botanists, and other professionals dedicated to fulfilling its mission.

Significance and Impact:

- The BSI plays a vital role in understanding and conserving India's rich plant diversity, estimated to include over 45,000 species.
- Their research contributes to scientific knowledge, informs conservation strategies, and supports sustainable development initiatives.
- By documenting and preserving plant life, the BSI safeguards India's natural heritage for future generations.

Zoological Survey of India (ZSI)

The Zoological Survey of India (ZSI) is a premier research organization functioning under the Union Ministry of Environment, Forest and Climate Change. ZSI has been actively involved since its inception in 1916, in the survey, exploration and research leading to the expansion of our knowledge on the immensely rich faunal diversity of our country.

- It originated as a Zoological Section of the Indian Museum in Kolkata.
- Initially, the ZSI had eight regional centers across India. Currently, there are 16 regional centers spread across the country.
- The headquarters is in Kolkata.
- It has been declared as a designated repository for the National Zoological Collection as per **Section 39 of the National Biodiversity Act, 2002.**

Objectives:

The ZSI has contributed significantly to knowledge and research on the fauna of the country. The primary objectives of the ZSI are:

- To promote the survey, exploration, research, and documentation on various aspects of animal taxonomy in the Indian subcontinent. It also seeks the advancement of knowledge on animal taxonomy.
- Make a status survey of the threatened and endemic species.
- Preparation of Red Data Book, Fauna of India, and Fauna of States.
- Bio-ecological studies on important communities/ species.
- Preparation of a database for the recorded species of the country.
- Maintenance and Development of National Zoological Collections.

Functions

The activities of the ZSI are coordinated by the Conservation and Survey Division under the Ministry of Environment, Forest, and Climate Change. Its functions are as follows:

- ZSI publishes the Red Data Book on Indian Animals. It was first published in 1983 and is similar to the Red Data Book published by IUCN.
- Publication of results including Fauna of India, Fauna of States, and Fauna of Conservation Areas.
- Training, Capacity Building, and Human Resource Development of the people involved.
- Geographic Information System (GIS) and Remote Sensing studies on recorded animal diversity as well as on threatened species.
- It works for the development of Environmental Information System (ENVIS) and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Centers. CITES is a multilateral treaty to protect endangered plants and animals.
- Conducts collaborative research programs on "Biodiversity" with other organisations in India and abroad.

National Tiger Conservation Authority (NTCA)

The National Tiger Conservation Authority (NTCA) is a statutory body established in 2006 under the Ministry of Environment, Forests and Climate Change (MoEFCC) of the Government of India. **The Wildlife Protection Act of 1972 was amended in 2006 to provide for constituting the NTCA.** The Minister for Environment & Forests is the Chairperson of the National Tiger Conservation Authority. Its primary mandate is to oversee and implement Project Tiger, an ongoing flagship conservation program aimed at protecting the endangered Bengal tiger in India.

Central Zoo Authority (CZA)

The Central Zoo Authority (CZA) was established in 1992 under Section 38A of the Wild Life (Protection) Act of 1972, with the primary objective of elevating Indian zoos to international standards and ensuring the welfare of animals. Governed by the Wild Life (Protection) Act of 1972 and the National Zoo Policy of 1998, the CZA plays a vital role in overseeing and regulating zoos across the country.

Objectives:

- **Addressing Animal Management Issues:**
  - Remedying inadequacies in animal management and housing conditions prevalent in Indian zoos before the formation of CZA.
- **Setting Standards:**
  - Establishing and enforcing minimum norms and standards for keeping animals in suitable conditions, ensuring their health and preventing ill-conceived and unplanned zoos.
- **Conservation Efforts:**
  - Complementing national efforts in conserving biodiversity, particularly fauna.
  - Supporting the conservation of endangered species through coordinated breeding under ex-situ conditions and raising stocks for rehabilitation in the wild.
- **Educational Objectives:**
  - Instilling empathy for wild animals in zoo visitors.
  - Promoting understanding and awareness of the importance of natural resource conservation and ecological balance.
- **Scientific Contribution:**
  - Providing opportunities for scientific studies useful for conservation and creating a database for sharing among organizations involved in in-situ and ex-situ conservation.
- **Rescue Centers:**
  - Serving as orphaned wild animal rescue centers, subject to the availability of appropriate housing and upkeep infrastructure.

Functions:

- **Guidelines and Rules:** Establishing guidelines and rules for the transfer of animals between zoos on a national and international scale.
- **Capacity Building:** Coordinating and implementing programs for zoo personnel capacity building, planned breeding programs, and ex-situ research.
- **Standards for Zoo Animal Care:** Establishing minimum standards for zoo animal housing, upkeep, and veterinary care.
- **Evaluation and Assessment:** Evaluating and assessing zoo operations in relation to prescribed standards or norms.
- **Coordination of Breeding Programs:** Coordinating the acquisition, exchange, and loaning of animals for breeding purposes.
- **Study Books:** Ensuring the upkeep of stud books for endangered species of wild animals bred in captivity.
- **Themes in Zoo Displays:** Identifying priorities and themes in the display of captive animals in a zoo.
- **Training and Research:**
  - Coordinating zoo personnel training in India and abroad.
  - Coordinating captive breeding research and educational programs for zoos.
- **Technical Assistance:** Providing zoos with technical and other assistance for proper management and development along scientific lines.
- **Other Functions:** Carrying out any other functions required to fulfill the purposes of the Act in relation to zoos.

Animal Welfare Board of India (AWBI)

The Animal Welfare Board of India (AWBI) is a statutory advisory body on animal welfare laws and promotes animal welfare in the country. It was established in 1962 under the

Prevention of Cruelty to Animals Act, 1960. The Animal Welfare Board of India was started under the stewardship of Late Smt. Rukmini Devi Arundale, well known humanitarian.

The AWBI's headquarters are located in **Ballabhgarh, Haryana.** The board consists of 28 members, including six members of parliament (two from the Rajya Sabha and four from the Lok Sabha). The members serve for a period of three years.

The AWBI's main functions include:

- Advising the central government on animal welfare issues.
- Framing guidelines for the care and handling of animals.
- Granting registration to animal welfare organizations.
- Investigating complaints of animal cruelty.
- Promoting animal welfare education and awareness.

Centre for Wetland Conservation and Management (CWCM)

The Centre for Wetland Conservation and Management (CWCM) is a dedicated institution established in India to address the crucial task of conserving and managing the country's wetlands.

Establishment and Mandate:

- Inaugurated in 2021 on World Wetland Day, the CWCM functions under the National Centre for Sustainable Coastal Management (NCSCM) in Chennai.
- Its primary mandate is to spearhead efforts in conserving, managing, and promoting the wise use of India's diverse wetlands.

Key Functions:

- **Addressing knowledge gaps and research needs:** The CWCM focuses on identifying and filling critical knowledge gaps related to wetland conservation and management in India.
- **Promoting integrated approaches:** It advocates for the implementation of integrated and comprehensive strategies that consider ecological, social, and economic aspects of wetland management.
- **Building partnerships and networks:** The center actively collaborates with various stakeholders, including national and international agencies, researchers, policymakers, and local communities, to foster collaborative efforts in wetland conservation.

Significance:

- Wetlands play a critical role in maintaining ecological balance, providing essential ecosystem services like flood control, water purification, and biodiversity conservation.
- The establishment of the CWCM highlights India's commitment to addressing wetland conservation challenges and ensuring the sustainable use of these vital ecosystems.

Forest Survey of India

It is an organization under the Ministry of Environment, Forest and Climate Change of the Government of India. It is responsible for assessing the forest cover of the country using satellite imagery and field surveys.

The FSI was established in 1981 and is headquartered in Dehradun, Uttarakhand. It carries out various activities and services, including:

- **Forest cover mapping:** The FSI uses satellite imagery to map the forest cover of the country at the state and district level. This information is published in the State of Forest Report (ISFR) every two years.
- **Forest inventory:** The FSI conducts field inventory to estimate the growing stock of forests. This information is used for forest management planning and monitoring.
- **Forest fire monitoring:** The FSI monitors forest fires using satellite data and provides alerts to state forest departments and other stakeholders.
- **Decision support system:** The FSI provides a decision support system that allows users to access high-resolution satellite imagery and ground details of forest cover.

The FSI plays an important role in monitoring and managing India's forest resources. The information it provides is essential for developing forest policies and programs, as well as for assessing the impact of climate change on forests.

National Board for Wildlife Conservation (NBWL)

The National Board for Wildlife (NBWL) is the apex body in India for all wildlife-related matters. It is primarily responsible for the promotion and development of wildlife conservation and the management of wildlife and forests.

It was established in 2003 under the Wildlife (Protection) Act of 1972. The NBWL is a statutory body with 47 members, including the Prime Minister.

- The other members include:
- 19 ex-officio members
- 15 non-government members
- 10 government officials, such as secretaries
- Three Members of Parliament
- Five NGOs
- 10 eminent ecologists, conservationists, and environmentalists

The NBWL is chaired by the Prime Minister of India. It can also establish a Standing Committee at its discretion. The committee will include the MoEFCC in charge as Vice-Chairperson, Member Secretary, and up to ten members nominated by the Vice-Chairperson.

Wildlife Crime Control Bureau (WCCB)

The Wildlife Crime Control Bureau (WCCB) is a statutory multi-disciplinary body under Wild Life (Protection) Act, 1972, established by the Government of India under the Ministry of Environment, Forest and Climate Change to combat organized wildlife crime in the country.

- **Founding:** Established in 2007 and became operational in 2008.
- **Headquarters:** New Delhi, India.
- **Mission:** To effectively curb wildlife crime and ensure the conservation of India's rich wildlife heritage.

Functions of the WCCB:

- Collect and collate intelligence related to organized wildlife crime activities and disseminate the same to State and other enforcement agencies for immediate action.
- Establish a centralized wildlife crime data bank.
- Coordinate actions by various agencies in connection with the enforcement of the provisions of the Wild Life (Protection) Act, 1972.
- Assist foreign authorities and international organizations concerned to facilitate coordination and universal action for wildlife crime control.
- Undertake capacity building of the wildlife crime enforcement agencies for scientific and professional investigation into wildlife crimes and assist State Governments to ensure success in prosecutions related to wildlife crimes.
- Advise the Government of India on issues relating to wildlife crimes having national and international ramifications, relevant policies and laws.

Structure of the WCCB:

- The WCCB is headed by a Director General, who is an Indian Police Service (IPS) officer of the rank of Director General of Police.
- The Bureau has five regional offices located in Delhi, Kolkata, Mumbai, Chennai and Jabalpur.
- Three sub-regional offices located at Guwahati, Amritsar and Cochin.
- Five border units located at Ramanathapuram, Gorakhpur, Motihari, Nathula and Moreh.

Recent Achievements of the WCCB:

- The Bureau has also been successful in securing the conviction of several high-profile wildlife criminals.
- It has received the Asia Environmental Enforcement Award-2020 awarded by the United Nations Environment Programme (UNEP).

Protected Areas

India has one of the largest networks of protected areas in the world, covering over 5% of its landmass. These include national parks, wildlife sanctuaries, and biosphere reserves, providing critical habitat for diverse species.

National Parks

An area, whether within a sanctuary or not, can be notified by the state government to be constituted as a National Park, by reason of its ecological, faunal, floral, geomorphological, or zoological association or importance, needed for the purpose of protecting & propagating or developing wildlife therein or its environment.

- There are 106 existing national parks in India covering an area of 44,402.95 km2, which is 1.35% of the geographical area of the country (National Wildlife Database Centre, Nov. 2023).

Wildlife Sanctuaries

Any area other than an area with any reserve forest or the territorial waters can be notified by the State Government to constitute as a sanctuary if such area is of adequate ecological, faunal, floral, geomorphological, natural or zoological significance, for the purpose of protecting, propagating or developing wildlife or its environment.

- There are 573 existing wildlife sanctuaries in India covering an area of 123,762.56 km, which is 3.76% of the geographical area of the country (National Wildlife Database Centre, Nov. 2023). Another 218 sanctuaries are proposed in the Protected Area Network Report covering an area of 16,829 km.

Note: For more details about Protected areas, refer Chapter-7 (protected areas network).

Conservation Reserves and Community Reserves in India

Conservation reserves and community reserves are protected areas in India that serve as buffer zones, connectors, and migration corridors between established national parks, wildlife sanctuaries, and reserved and protected forests. These categories were introduced in the Wildlife (Protection) Amendment Act of 2003.

Biodiversity Heritage Sites (BHS)

Biodiversity Heritage Sites (BHS) are areas of biodiversity importance in India that are notified by the State Government in consultation with local bodies under the Biological Diversity Act, 2002. These areas are unique and ecologically fragile ecosystems that have rich biodiversity, cultural, ethical or aesthetic values, and may have a long history of human association with them.

There are currently 36 BHS in India, spread across 15 states and union territories. Some of the BHS are:

- **Majuli** in Assam, the world's largest river island formed by the Brahmaputra River, known for neo-Vaishnavite monasteries and tribal communities.
- **Nallur Tamarind Grove** in Karnataka, is a surviving historical site from the Chola dynasty period with about 300 large and old tamarind trees.
- **Mahendragiri hill** in Odisha, India's latest BHS and a part of the Eastern Ghats, has tropical shola, tropical semi-evergreen, and dry deciduous forests with many endemic and threatened species.

- **Hajong Tortoise Lake** in Assam, the only natural tortoise habitat in Assam, home to the freshwater Black Softshell Turtle and the Indian Peacock Softshell Turtle.
- **Urumbi** in Karnataka is a unique environmental system on the banks of Kumaradhara river, with sacred groves, wetlands, and medicinal plants.

India's legislative and policy framework, coupled with its institutional structure and extensive network of protected areas, demonstrates a comprehensive commitment to biodiversity conservation. Policymakers, scientists, and conservationists continually strive to strengthen these frameworks, ensuring the sustainable management of India's rich biological resources for future generations.

GLOBAL EFFORTS FOR BIODIVERSITY CONSERVATION

Protecting and conserving biodiversity is a global challenge crucial for ensuring the health of our planet and securing its resources for future generations. Fortunately, several international efforts are tackling this complex issue at various levels.

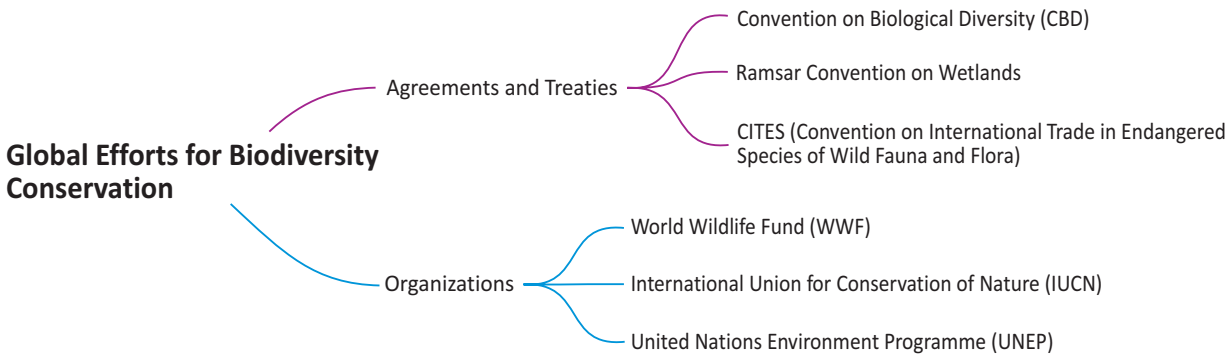

Global Efforts for Biodiversity Conservation
Agreements and Treaties
Convention on Biological Diversity (CBD)
Ramsar Convention on Wetlands
CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora)
Organizations
World Wildlife Fund (WWF)
International Union for Conservation of Nature (IUCN)
United Nations Environment Programme (UNEP)

Fig. 6.4: Global Efforts for Biodiversity Conservation

IGNITE YOUR MIND

National Treasures: Unveiling the Gems in India's Crown

Journey through India's diverse network of protected areas, from sprawling national parks teeming with wildlife to serene sanctuaries safeguarding endangered species. Uncover the intricate differences in their management practices and levels of protection. Imagine yourself as a park ranger on the frontlines of conservation. What challenges would you face in protecting these natural treasures, and how could you overcome them?

INTERNATIONAL AGREEMENTS

1. United Nations Convention on Biological Diversity

The Convention on Biological Diversity (CBD) is a landmark **international legally binding agreement** of the United Nations and plays a central role in global biodiversity conservation efforts.

Background

- Adopted in 1992 at the Rio Earth Summit, it became the first internationally binding agreement specifically focused on the conservation and sustainable use of biodiversity.
- It establishes principles for nations to safeguard biodiversity, promote sustainable utilization, and encourage fair and equitable sharing of benefits.
- Its objective is to secure a groundbreaking agreement to stop and reverse the decline of biodiversity, similar to the 2015 Paris Agreement on climate change.
- The Secretariat of the Convention on Biological Diversity is located in Montreal, Canada.
- Currently, 196 countries are parties to the Convention, reflecting its global reach and importance.
- India enacted Biological Diversity Act, 2002 for giving effect to the provisions of the CBD.

The CBD has Three Main Objectives

- **Conservation of biological diversity:** Protecting the variety of life on Earth at all levels (genetic, species, and ecosystem).
- **Sustainable use of its components:** Utilizing biodiversity in a way that meets human needs without compromising its long-term health.
- **Fair and equitable sharing of benefits** arising from the use of genetic resources: Ensuring that access to and utilization of genetic resources benefits both providers and users, particularly developing countries.

Key Features

- **National Biodiversity Strategies and Action Plans (NBSAPs):** Each member country develops a national plan outlining its conservation priorities and actions according to the CBD's objectives.

- **Biosafety Protocol:** A supplementary agreement regulating the deliberate release of genetically modified organisms into the environment to minimize potential risks to biodiversity.
- **Conference of the Parties (COP):** The governing body of the Convention, where member countries meet every two years to review progress, set new goals, and make decisions.
- **Achievements:** CBD has led to the development of key initiatives and programs, including the Strategic Plan for Biodiversity 2011-2020 and the Global Biodiversity Outlook reports.
- **Nagoya Protocol:** CBD played a crucial role in the adoption of the Nagoya Protocol, addressing access to genetic resources and the fair and equitable sharing of benefits.

Strategic Plan for Biodiversity 2011-2020

- CBD adopted **Aichi Biodiversity** Targets at Nagoya Conference in 2010. The Aichi Biodiversity Targets laid out a 10 year plan (Strategic Plan for Biodiversity 2011-2020).
- The plan included five strategic goals and 20 ambitious yet achievable targets, collectively known as the Aichi Targets. This plan served as a ten-year framework for countries and stakeholders to address biodiversity loss.
- Its vision aimed for "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people."
- **Aichi Targets:** The Aichi Targets were adopted by the CBD at its Nagoya conference. These targets provide a set of strategic goals and actions to be achieved by the global community to address biodiversity loss. They covered a broad range of areas, including:
  - Addressing the underlying causes of biodiversity loss (e.g., reducing pollution, unsustainable consumption).
  - Protecting ecosystems, species, and genetic diversity.
  - Sustainable use of biodiversity.
  - Enhancing implementation through participatory planning, resource mobilization, and capacity building.

Protocols under the CBD

- **Cartagena Protocol on Biosafety:**
  - Adopted in 2000 as a supplementary agreement to the Convention on Biological Diversity (UNCBD).
  - Aims to protect biological diversity from potential risks posed by living modified organisms (LMOs) resulting from modern biotechnology.
  - Establishes an Advance Informed Agreement (AIA) procedure to ensure that countries are provided with the necessary information before agreeing to the import of such organisms into their territory.
  - Establishes a Biosafety Clearing-House to facilitate the exchange of information on living modified organisms.
  - India has ratified this protocol.
- **Nagoya Protocol on Access and Benefit Sharing:**
  - The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) was adopted in 2010 in Nagoya, Japan at COP10.
  - Aims to share the benefits arising from the utilization of genetic resources in a fair and equitable way.
  - Promotes appropriate access to genetic resources and the transfer of relevant technologies.
  - India has signed and ratified this protocol.
- **Nagoya Kuala Lumpur Protocol:**
  - The Nagoya-Kuala Lumpur Supplementary Protocol on Liability and Redress is an international treaty adopted in 2010 and signed in 2011.
  - It is a binding agreement to the Cartagena Protocol on Biosafety, which is part of the Convention on Biological Diversity.
  - The protocol's goal is to help conserve and use biological diversity sustainably while also considering risks to human health.
  - It provides international rules and procedures for liability and redress related to living modified organisms.

These protocols are integral components of the CBD, addressing specific aspects related to biosafety and the fair and equitable sharing of benefits from genetic resources. They enhance the comprehensive approach of the CBD towards biodiversity conservation and sustainable use.

Issues in Achieving Aichi Targets

- **Lack of Clear and Measurable Targets:** Many Aichi Targets were worded vaguely, making it difficult to track progress and assess success. This ambiguity also created challenges in setting national and regional goals that aligned with the global framework.
- **Insufficient Funding:** Implementing effective conservation measures requires significant financial resources, particularly in developing countries. The Aichi Targets lacked a concrete plan for mobilizing the necessary funds, leading to a significant funding gap throughout the decade.

- **Inadequate Capacity and Expertise:** Implementing large-scale conservation initiatives requires trained personnel and specialized knowledge. Many countries, especially developing nations, lacked the capacity and expertise to effectively implement the Aichi Targets due to limited resources and personnel.
- **Limited Stakeholder Engagement:** Achieving biodiversity conservation requires collaboration between various stakeholders, including governments, businesses, indigenous communities, and civil society. Insufficient engagement with these groups hindered the implementation of effective conservation strategies.
- **Complex and Conflicting Policies:** In some cases, existing policies related to agriculture, infrastructure development, and resource management conflicted with the goals of the Aichi Targets. This lack of policy coherence made it difficult to reconcile economic development with biodiversity conservation.

Way Forward

- **Setting Clear and Ambitious Targets:**
  - Clearly define goals with specific, measurable, achievable, relevant, and time-bound (SMART) indicators.
  - Develop national and regional targets aligned with the global framework, considering local contexts and priorities.
- **Mobilizing Financial Resources:**
  - Develop a robust financial plan with diverse funding sources, including public and private investments, innovative financing mechanisms, and debt-for-nature swaps.
  - Establish transparent and accountable mechanisms for allocating and utilizing funds effectively.
- **Building Capacity and Expertise:**
  - Invest in capacity building programs for developing countries, providing training and technical assistance in crucial areas like conservation planning, monitoring, and sustainable resource management.
  - Foster knowledge sharing and collaboration between developed and developing countries through partnerships and exchange programs.
- **Strengthening Stakeholder Engagement:**
  - Promote active participation of all stakeholders, including indigenous communities, local communities, NGOs, and private sector, in decision-making and implementation processes.
  - Develop inclusive and transparent governance structures that ensure equitable participation and benefit sharing.

COP15 to the United Nations Convention on Biological Diversity (CBD)

Global Biodiversity Framework

- **Adoption:** The 15th Conference of Parties (COP) to the UN Convention on Biological Diversity adopted the "Kunming-Montreal Global Biodiversity Framework" (GBF) during its meeting held in Kunming, China.
- **Theme:** The theme of the conference was "Ecological Civilization: Building a Shared Future for All Life on Earth."
- **Framework Content:** The Global Biodiversity Framework is a comprehensive set of targets and goals developed by the United Nations Convention on Biological Diversity (CBD) to guide international efforts for biodiversity protection and conservation.
- **Targets:** The framework outlines 4 Global goals for 2050 and 23 targets for 2030 addressing issues such as land and sea area protection, ecosystem restoration, pollution reduction, sustainable agriculture, renewable energy, indigenous community participation, gender equality, financial resource mobilization, and more.

COP 15 CBD Highlights

- **A Roadmap for Nature:** COP 15 established a comprehensive framework with 4 key goals and 23 specific targets to tackle biodiversity loss. Protecting land and oceans, reducing habitat destruction, and promoting sustainable practices are central themes.
- **Addressing the Root Causes:** The framework acknowledges the need to address underlying drivers of biodiversity loss, such as habitat destruction, overexploitation, and climate change. It emphasizes the importance of restoration and sustainable production patterns.
- **Mobilizing Resources:** The framework calls for increased financial resources from various sources, including governments, the private sector, and innovative financing mechanisms. The private sector is encouraged to play a more active role in supporting conservation efforts.
- **Empowering Local Communities:** The framework recognizes the vital role of indigenous people and local communities in protecting and managing biodiversity. It emphasizes respecting their rights, traditional knowledge, and active participation in decision-making processes.
- **Sharing Benefits Fairly:** The framework highlights the importance of fair and equitable sharing of benefits arising from the use of genetic resources. This ensures that benefits are distributed justly and the rights of indigenous communities are protected.
- **30x30 Initiative:** The ambitious 30x30 initiative aims to conserve at least 30% of the planet's land and oceans as protected areas by 2030. This critical goal plays a key role in addressing biodiversity loss and safeguarding the health of our planet for future generations.

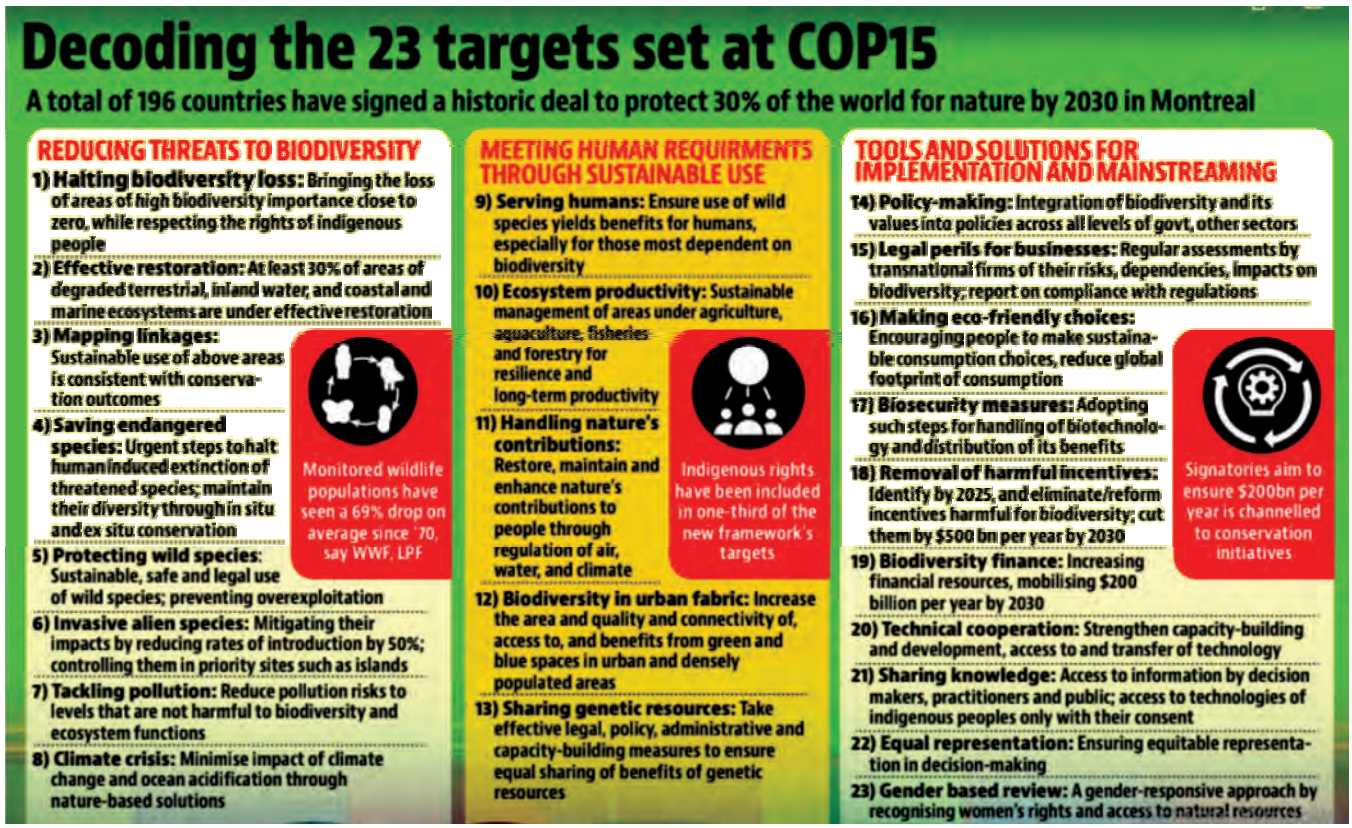

Decoding the 23 targets set at COP15
A total of 196 countries have signed a historic deal to protect 30% of the world for nature by 2030 in Montreal
REDUCING THREATS TO BIODIVERSITY
1) Halting biodiversity loss: Bringing the loss of areas of high biodiversity importance close to zero, while respecting the rights of indigenous people
2) Effective restoration: At least 30% of areas of degraded terrestrial, inland water, and coastal and marine ecosystems are under effective restoration
3) Mapping linkages: Sustainable use of above areas is consistent with conservation outcomes
4) Saving endangered species: Urgent steps to halt human-induced extinction of threatened species; maintain their diversity through in situ and ex situ conservation
Monitored wildlife populations have seen a 69% drop on average since '70, say WWF, LPF
5) Protecting wild species: Sustainable, safe and legal use of wild species; preventing overexploitation
6) Invasive alien species: Mitigating their impacts by reducing rates of introduction by 50%; controlling them in priority sites such as islands
7) Tackling pollution: Reduce pollution risks to levels that are not harmful to biodiversity and ecosystem functions
8) Climate crisis: Minimise impact of climate change and ocean acidification through nature-based solutions
MEETING HUMAN REQUIRMENTS THROUGH SUSTAINABLE USE
9) Serving humans: Ensure use of wild species yields benefits for humans, especially for those most dependent on biodiversity
10) Ecosystem productivity: Sustainable management of areas under agriculture, aquaculture, fisheries and forestry for resilience and long-term productivity
11) Handling nature's contributions: Restore, maintain and enhance nature's contributions to people through regulation of air, water, and climate
Indigenous rights have been included in one-third of the new framework's targets
12) Biodiversity in urban fabric: Increase the area and quality and connectivity of, access to, and benefits from green and blue spaces in urban and densely populated areas
13) Sharing genetic resources: Take effective legal, policy, administrative and capacity-building measures to ensure equal sharing of benefits of genetic resources
TOOLS AND SOLUTIONS FOR IMPLEMENTATION AND MAINSTREAMING
14) Policy-making: Integration of biodiversity and its values into policies across all levels of govt, other sectors
15) Legal perils for businesses: Regular assessments by transnational firms of their risks, dependencies, impacts on biodiversity; report on compliance with regulations
16) Making eco-friendly choices: Encouraging people to make sustainable consumption choices, reduce global footprint of consumption
17) Biosecurity measures: Adopting such steps for handling of biotechnology and distribution of its benefits
18) Removal of harmful incentives: Identify by 2025, and eliminate/reform incentives harmful for biodiversity; cut them by $500 bn per year by 2030
Signatories aim to ensure $200bn per year is channelled to conservation initiatives
19) Biodiversity finance: Increasing financial resources, mobilising $200 billion per year by 2030
20) Technical cooperation: Strengthen capacity-building and development, access to and transfer of technology
21) Sharing knowledge: Access to information by decision makers, practitioners and public; access to technologies of indigenous peoples only with their consent
22) Equal representation: Ensuring equitable representation in decision-making
23) Gender based review: A gender-responsive approach by recognising women's rights and access to natural resources

Fig. 6.5: Targets of COP 15

UN DECADE ON ECOSYSTEM RESTORATION

The UN Decade on Ecosystem Restoration is a global initiative jointly coordinated by the United Nations Environment Programme (UNEP) and the United Nations Food and Agriculture Organization (FAO) with the ambitious goal of preventing, halting, and reversing the degradation of ecosystems on every continent and in every ocean by 2030. It aims to achieve this by:

- **Raising awareness:** Highlighting the critical role of healthy ecosystems for human well-being and planetary health.
- **Promoting global cooperation:** Encouraging governments, businesses, and individuals to work together towards shared restoration goals.
- **Supporting restoration efforts:** Providing resources, knowledge, and expertise to facilitate effective restoration projects around the world.

The Decade Focuses on Several Key Areas

- **Restoring a wide range of ecosystems:** This includes forests, wetlands, grasslands, mountains, and marine environments.
- **Addressing the root causes of degradation:** This involves tackling issues like climate change, pollution, unsustainable land use, and overexploitation.
- **Building capacity and knowledge:** Empowering communities, organizations, and individuals with the skills and knowledge needed to undertake successful restoration initiatives.
- **Financing restoration:** Identifying and securing financial resources to support restoration efforts at all scales.

The UN Decade on Ecosystem Restoration is a crucial effort to address the global challenge of ecosystem degradation. By working together, we can restore our planet's natural world and ensure a healthy future for all.

World Restoration Flagships

- World Restoration Flagships of the UN Decade on Ecosystem Restoration are distinguished initiatives recognized by the United Nations for their exemplary contributions to large-scale and long-term ecosystem restoration.
- **Recognition Criteria:** These initiatives are acknowledged for their alignment with the Ten Restoration Principles of the UN Decade on Ecosystem Restoration, promoting best practices in restoration. They become eligible for UN-backed support, promotion, advice, and funding.
- **Initiatives:** The selected initiatives represent successful and impactful ecosystem restoration projects from various regions, contributing significantly to the restoration of natural ecosystems.
- **Future Calls:** Regular calls for World Restoration Flagships will continue until 2030, offering ongoing opportunities for initiatives to be recognized.

2022 World Restoration Flagships

The ten initiatives recognized as the 2022 World Restoration Flagships during COP15 in Montreal are:

- Trinational Atlantic Forest Pact (Brazil, Paraguay, and Argentina)
- Abu Dhabi Marine Restoration (UAE)
- Great Green Wall (African Union)
- **Namami Gange (India)**
- Multi-Country Mountain Initiative (Serbia, Kyrgyzstan, Uganda, and Rwanda)
- Small Island Developing States Restoration Drive (Vanuatu, St Lucia, and Comoros)
- Altyn Dala Conservation Initiative (Kazakhstan)
- Central American Dry Corridor (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama)
- Building with Nature (Indonesia)
- Shan-Shui Initiative (China)

Recently 7 More Initiatives have Joined the List

- TERAI ARC LANDSCAPE (Nepal)
- RESTORING MEDITERRANEAN FORESTS (Lebanon, Morocco, Tunisia, Türkiye)
- REGREENING AFRICA (Ethiopia, Ghana, Kenya, Mali, Niger, Rwanda, Senegal, Somalia)
- MANGROVE REGENERATION IN SRI LANKA (Sri Lanka)
- LIVING INDUS (Pakistan)
- AFRICAN FARMERS TRANSFORMING FOOD SYSTEMS (Mali, Senegal, Tanzania, Uganda, Kenya)
- ACCIÓN ANDINA (Argentina, Bolivia, Chile, Ecuador, Perú)

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora)

- CITES, also known as the Washington Convention, is a multilateral treaty adopted in 1973 and which came into force in 1975.
- Its objective is to safeguard threatened flora and fauna from the dangers arising from global commerce. The draft decisions reached during the 19th Conference of Parties (COP19) to CITES in Panama City specifically tackle the potential hazards of future zoonotic diseases linked to the international trade of wildlife, particularly in light of the COVID-19 pandemic.

Key Points About CITES

- **Formation and Entry into Force:**
  - Formed as a result of a resolution adopted in 1963 at a meeting of members of IUCN.
  - Came into force in 1975.
  - CITES Secretariat is administered by UNEP and is located in Geneva, Switzerland.
  - India hosted COP-3 in 1981.
- **Parties of the Convention:**
  - States and regional economic integration organizations adhere to CITES voluntarily.
  - Parties are countries that have agreed to be bound by the Convention.
  - CITES is legally binding on the Parties, and they are required to implement the Convention.
  - India has been a party to the Convention on International Trade in Endangered Species (CITES) since 1976.
    - India passed the Wild Life (Protection) Amendment Act, 2022 to comply with the CITES.
- **Significance:**
  - Aims to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species.
  - Provides a framework for international cooperation to regulate wildlife trade for conservation purposes.
  - Controls international trade in specimens of selected species through a licensing system.
  - Each Party designates Management Authorities and Scientific Authorities to administer the licensing system and advise on the effects of trade on species.
  - Species are listed in Appendices I, II, and III based on the degree of protection they need.
- **Appendices:**
  - **Appendix I:** Includes species threatened with extinction, and trade is permitted only in exceptional circumstances.
  - **Appendix II:** Includes species not necessarily threatened with extinction, but trade must be controlled to avoid incompatible utilization.
  - **Appendix III:** Contains species protected in at least one country seeking assistance from other CITES Parties in controlling trade.
- **CITES COP19 2022:**
  - Addressed risks of zoonotic diseases associated with international wildlife trade, inspired by the emergence of diseases like COVID-19.
  - Formulating decisions aimed at minimizing the risks associated with the dissemination of pathogens, spillover events, and the transmission of zoonotic diseases through global supply chains in the wildlife trade.
  - Encouraged consultation with organizations like FAO, WHO, International Consortium on Combating Wildlife Crime, and Convention on Biological Diversity.
- **India and CITES COP19:**
  - Red-crowned roofed turtles and Leith's soft-shell turtle from India made it to Appendix I, indicating high protection.

- India relaxed restrictions on the export of furniture and handicrafts made of North Indian rosewood (shisham).
- Notably, India decided not to vote against a proposal to reopen the international trade in ivory, marking a shift in its stance on the ivory trade.

International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)

❑ **Adoption and Entry into Force:**

- Adopted in November 2001 at Rome during the 31st session of the Food and Agriculture Organization of the United Nations (FAO).
- Entered into force on June 29, 2004.
- Currently has 149 Contracting Parties, including India.

❑ **Objectives:**

- The treaty aims to achieve food and nutritional security and promote climate-resilient agriculture.
- Recognizes the significant contribution of indigenous people and small-holder farmers as traditional custodians of the world's food crops.

❑ **Key Principles:**

- Acknowledges the enormous contribution of farmers to the diversity of crops globally.
- Establishes a global system to provide farmers, plant breeders, and scientists with access to plant genetic materials.
- Ensures that recipients share benefits derived from the use of these genetic materials with the countries where they originated.

❑ **Global Cooperation:**

- Recognizes the interdependence of countries for Plant Genetic Resources for Food and Agriculture (PGRFA).
- Aims to facilitate access and benefit-sharing on a global scale.

❑ **Access and Benefit Sharing:**

- Provides a framework for fair and equitable sharing of benefits arising from the use of plant genetic resources.
- Promotes access to genetic materials while ensuring that the countries providing these resources receive a fair share of the benefits.

The ITPGRFA plays a crucial role in fostering international cooperation, preserving genetic diversity, and addressing the challenges of food security and climate resilience in agriculture. It emphasizes the importance of recognizing and respecting the contributions of farmers and indigenous communities to global crop diversity.

IGNITE YOUR MIND

A Global Village for Conservation: Working Together Across Borders

The fight for biodiversity conservation transcends national boundaries. Delve into international agreements like the Convention on Biological Diversity, and understand how they foster global cooperation in this critical endeavor. Imagine countries as members of a club, working together to achieve a common goal. What are the challenges and opportunities that arise in this collaborative effort, and how can we overcome them to ensure a united front for protecting our planet's irreplaceable biodiversity?

UN High Seas Treaty (Treaty of High Seas)

The UN High Seas Treaty, also known as the Treaty of High Seas or **Biodiversity Beyond National Jurisdiction (BBNJ) Treaty,** is a historic international agreement negotiated under the United Nations Convention on the Law of the Sea (UNCLOS) of 1982. It is also referred as "Paris agreement for the oceans and covers areas beyond EEZ of countries that is 200 nautical miles from coast.

❑ It represents the first-ever treaty aimed at the protection of biodiversity on the high seas.

❑ The treaty establishes a legal framework to manage and conserve marine life in areas beyond national jurisdiction, placing about 30% of the world's international waters into protected areas by 2030.

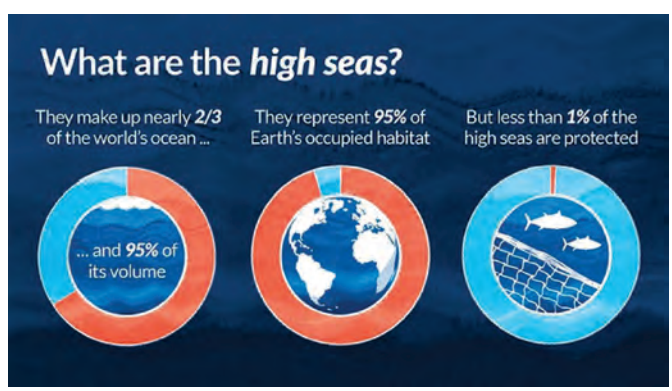

What are the high seas?
They make up nearly 2/3 of the world's ocean ...
... and 95% of its volume
They represent 95% of Earth's occupied habitat
But less than 1% of the high seas are protected

Fig. 6.6: The High Seas

Key Features and Significance

❑ **Negotiation Process:**

- Initiated in 2017 through an Inter-Governmental Conference under UNCLOS, negotiations began. The resulting treaty is internationally binding and focuses on the effective management and protection of the high seas.

- **Focus Areas of the Treaty (BBNJ Treaty):**
  - Conservation and sustainable use of marine biological diversity in Areas Beyond National Jurisdiction (ABNJ), including marine genetic resources.
  - Establishment of area-based management tools, such as Marine Protected Areas (MPAs).
  - Implementation of environmental impact assessments for activities like deep-sea mining.
  - Capacity building and the transfer of marine technology.
- **Approval and Targets:** The High Seas Treaty was approved by the UN on March 4, 2023. It aims to designate 30% of the world's international waters as protected areas (MPAs) by 2030.
- **Marine Protected Areas (MPAs):** The treaty permits the creation of substantial MPAs to prevent species extinction and distribute the genetic richness of the high seas. Governance of MPAs will be overseen by the Conference of the Parties (COP) to ensure accountability for member nations regarding governance and biodiversity.
- **Sharing of Marine Genetic Resources:** The treaty addresses the sharing of marine genetic resources, encompassing biological material from oceanic plants and animals, with potential benefits for pharmaceuticals and food.
- **Environmental Impact Assessments:** Mandating environmental impact assessments for activities like deep-sea mining, the treaty aims to ensure responsible and sustainable practices.
- **Global Ocean Health and Conservation:** The treaty aims to enable holistic and equitable management of human activities affecting ocean life beyond national boundaries. It safeguards global ocean health, climate resilience, socio-economic well-being, and food security.
- **International Collaboration:** Facilitating collaboration between countries to address climate change, biodiversity loss, and pollution, the treaty contributes to global efforts in achieving sustainable development goals.
- **Scope:** Referred to as the "Treaty of the High Seas," it concentrates on the conservation and sustainable use of marine biological diversity beyond national jurisdiction as defined by UNCLOS. This includes areas beyond exclusive economic zones or national waters.
- **Significance:** Covering nearly half of the Earth's surface, including areas with minimal regulation and exploration for biodiversity, the treaty holds immense global importance.
- **Launch and Negotiations:** Launched at the One Ocean Summit in February 2022, negotiations revolve around key elements agreed upon in 2015. These elements include marine genetic resources, area-based management tools, environmental impact assessments, capacity-building, and the transfer of marine technology.

Necessity of a Legally Binding Agreement for BBNJ

- **Critical for the Health of Oceans:** The well-being of oceans, coastal areas, and overall planetary sustainability relies on the preservation of biodiversity in regions beyond national jurisdiction.
- **Significant Ecological and Economic Advantages:** Comprising 95% of the ocean, these areas yield ecological, economic, social, cultural, scientific, and food-security benefits.
- **Increasing Vulnerability and Threats:** Regions beyond national jurisdiction are increasingly susceptible to threats such as pollution, overexploitation, and the impacts of climate change.
- **Rising Demand for Marine Resources:** The escalating demand for marine resources poses risks to these areas, jeopardizing biodiversity and ecosystems.
- **Concerns Surrounding Deep-Sea Mining:** Apprehensions exist about the potential impact of deep-sea mining on the biodiversity of the deep seafloors.
- **Crucial Role of a Conservation Framework:** To address conservation needs, there is a pressing requirement for a legally binding instrument to manage and regulate biodiversity in areas beyond national jurisdiction.

The BBNJ Treaty is a significant step forward in international ocean governance. It is hoped that the treaty will help to ensure the health of our oceans for future generations.

Bonn Convention on Migratory Species

The Bonn Convention on Migratory Species of Wild Animals, also known as CMS or the Bonn Convention, is an international agreement under the United Nations Environment Programme (UNEP) that aims to conserve migratory species throughout their ranges. Signed in 1979, the Convention entered into effect in 1983 and currently has 133 Parties. It is the only global intergovernmental treaty specifically dedicated to the conservation of migratory animals and their habitats.

- **It has two Appendices.**
  - Appendix I lists endangered migratory species and includes prohibitions regarding the taking of these species.
  - Appendix II lists species that have an 'unfavourable conservation status' (as per the conditions set out in the Convention) and encourages range states to draft range-wide agreements for conservation and management of these species.

The Convention provides a framework for international cooperation for the conservation of migratory species and their habitats by:

- Promoting the development and implementation of agreements and action plans for migratory species;
- Providing a framework for international cooperation on research and monitoring;

- Encouraging the range States of migratory species to coordinate their conservation efforts;
- Assisting developing countries in the conservation of migratory species.

The Convention covers a wide range of migratory species, including birds, mammals, reptiles, amphibians, fish, and invertebrates. Some of the well-known species covered by the Convention include whales, dolphins, porpoises, sea turtles, sharks, birds of prey, bats, elephants, lions, and cheetahs.

The Convention works through a number of mechanisms, including:

- **Agreements:** CMS encourages the development of Agreements for specific migratory species or groups of species. These Agreements are negotiated and adopted by the Parties to CMS and address specific conservation needs of the species or group of species in question.
- **Action Plans:** Action Plans are non-legally binding instruments that provide guidance to Range States on how to conserve migratory species. They are developed by technical working groups and then adopted by the CMS Standing Committee.
- **Scientific Council:** The CMS Scientific Council provides advice to the CMS Parties on the conservation of migratory species.
- **Secretariat:** The CMS Secretariat is located in Bonn, Germany, and provides administrative and technical support to the Convention.
- **COP:** The Conference of Parties (COP) is the decision-making organ of this convention.
  - In 2020, India hosted COP 13 at Gandhi Nagar, Gujarat.

Bonn COP 14

The 14th Meeting of the Conference of the Parties (COP14) to the Convention on the Conservation of Migratory Species of Wild Animals (CMS) concluded in Samarkand, Uzbekistan.

Some of the outcomes include:

- Some of the species included in the CMS Appendices were Eurasian lynx, sand tiger shark, Pallas's cat, and magellanic plover, among others.
- The summit also gave added safeguards to species such as blue shark, chimpanzee and straw-coloured fruit bat through New Concerted Actions adopted by range states.
- The Parties also extended ongoing efforts to safeguard species already included in concerted actions, such as the giraffe, antipodean albatross, Atlantic humpback dolphin and others.
- The COP14 played a key role in giving recognition to the Central Asian Flyway for migratory birds that stretches from Siberia all the way to the Maldives.
- Observing the insect decline and its potential threats to migratory insectivorous animals, the COP14 also endorsed a new scientific report on the same.
- For migratory aquatic species, it introduced a new mandate on understanding the impacts on migratory species, their prey and ecosystems due to deep-seabed mining.
- The COP also introduced three action plans for aquatic species, such as Hawksbill turtle, threatened with exploitation for their use and trade.
  - It also had new plans for Angelshark, which has seen a steady decline in 50 years and become "exceedingly rare" in its historical range.

World Heritage Convention

- The World Heritage Convention, formally the Convention Concerning the Protection of the World Cultural and Natural Heritage, is an international treaty adopted by the General Conference of UNESCO on November 16, 1972. It came into effect in 1975.
- The Convention establishes a framework for the identification, protection, and preservation of cultural and natural heritage around the world considered to be of outstanding universal value to humanity.
- As of November 2023, 195 countries have ratified the Convention, making it one of the most widely ratified international agreements in existence.
- The Convention defines the types of sites that can be considered for inscription on the World Heritage List, which includes both cultural and natural heritage sites.
- Cultural heritage sites include monuments, architectural ensembles, sites, and cultural landscapes. Examples of cultural heritage sites include the Taj Mahal in India, the Great Wall of China, and the Pyramids of Giza in Egypt.
- Natural heritage sites include outstanding physical, biological and geological formations, habitats of rare and endangered species, and areas with exceptional natural beauty. Examples of natural heritage sites include the Grand Canyon in the United States, the Great Barrier Reef in Australia, and the Galapagos Islands in Ecuador.

The Convention also establishes a number of mechanisms for the protection and conservation of World Heritage sites, including:

- **The World Heritage Committee:** This intergovernmental committee is responsible for the implementation of the Convention, including the inscription of sites on the World Heritage List and the List of World Heritage in Danger.
- **The World Heritage Fund:** This fund provides financial assistance to States Parties for the conservation of World Heritage sites.
- **Technical assistance:** UNESCO provides technical assistance to States Parties for the identification, protection, and conservation of World Heritage sites.

REDD+

- 'REDD' stands for **'Reducing emissions from deforestation and forest degradation** in developing countries. The '+' stands for additional forest-related activities that protect the climate, namely sustainable management of forests and the conservation and enhancement of forest carbon stocks. Under the framework with these REDD+ activities, developing countries can receive results-based payments for emission reductions when they reduce deforestation. This serves as a major incentive for their efforts.
- Proper implementation of the REDD+ strategies can help in tackling:
  - Forest degradation and biodiversity loss.
  - Improving Social standards reducing poverty.
  - Resilience of forest ecosystem.

The Economics of Ecosystems and Biodiversity (TEEB)

- The TEEB study was launched by Germany and the European Commission in response to a proposal by the G8+5 Environment Ministers in Potsdam, Germany in 2007, to develop a global study on the economics of biodiversity loss.
- The second phase of the TEEB study is hosted by the United Nations Environment Programme (UNEP) with support from a number of organizations, including the European Commission, Germany, UK and Nature Conservation and Nuclear Safety.
- TEEB is focused on "making nature's values visible". Its principal objective is to mainstream the values of biodiversity and ecosystem services into decision-making at all levels. It aims to achieve this goal by following a structured approach to valuation that helps decision-makers recognize the wide range of benefits provided by ecosystems and biodiversity, demonstrate their values in economic terms and, where appropriate, capture those values in decision-making.

INTERNATIONAL ORGANIZATIONS IN BIODIVERSITY CONSERVATION

There are many international organizations working on biodiversity conservation, each with its own specific focus and area of expertise. Here are a few of the most prominent:

Role of United Nations Environment Programme (UNEP)

- UNEP plays a crucial role in coordinating global efforts for biodiversity conservation through various initiatives and conventions, including:
  - **Convention on Biological Diversity (CBD):** Provides a framework for national action and international cooperation for the conservation and sustainable use of biodiversity.
  - **Strategic Plan for Biodiversity 2021-2030:** Sets ambitious goals and targets for biodiversity conservation, including halting biodiversity loss by 2030.
  - **Post-2020 Global Biodiversity Framework:** Currently under negotiation, this framework aims to set a new global biodiversity agenda beyond 2020.
- UNEP also supports countries in developing national biodiversity strategies and action plans, mainstreaming biodiversity into development planning, and promoting sustainable practices in sectors like agriculture, forestry, and tourism.
- **Role of Food and Agriculture Organization (FAO):** FAO works to improve food security and nutrition, eliminate hunger, and promote sustainable agriculture and rural development.

  Link to Biodiversity Conservation:
  - FAO recognizes the critical role of biodiversity in sustainable agriculture and food production. Its activities in this area include:
    - Promoting the conservation and use of agricultural biodiversity, such as traditional crop varieties and livestock breeds.
    - Supporting the development of sustainable agricultural practices that minimize negative impacts on biodiversity, such as reduced use of pesticides and fertilizers.
    - Encouraging the integration of biodiversity considerations into national agricultural policies and programs.
  - FAO also works on related issues like land degradation, climate change, and water management, which are all interconnected with biodiversity conservation.
- **Role of World Wildlife Fund (WWF):** WWF is one of the world's leading independent conservation organizations, working in over 100 countries on a wide range of issues, including:
  - **Species conservation:** Focusing on endangered and iconic species like tigers, rhinos, and elephants.
  - **Habitat protection:** Working to conserve critical ecosystems like forests, coral reefs, and wetlands.
  - **Promoting sustainable practices:** Advocating for policies and practices that reduce human impact on the environment, such as sustainable forestry and fisheries.
  - **Engaging Communities:** Empowering local communities to participate in conservation efforts and manage their natural resources sustainably.
- **Role of International Union for Conservation of Nature (IUCN):** IUCN is the world's largest and most diverse environmental network, bringing together governments, NGOs, scientists, and other stakeholders to conserve nature and accelerate the transition to a sustainable future.

Key Functions:

- Setting global conservation standards through tools like the Red List of Threatened Species and Protected Areas Categories.
- Providing scientific expertise and policy guidance to governments and other actors on conservation issues.
- Convening global forums and facilitating international cooperation on conservation.
- Supporting capacity building and knowledge sharing for effective conservation action.

By understanding the specific roles and contributions of these organizations, you can gain a comprehensive perspective on the multifaceted approach to addressing biodiversity conservation challenges at the international level.

IGNITE YOUR MIND

The Red List: A Code Red for Endangered Species

Not all species are created equal. The IUCN Red List acts as a global barometer for biodiversity health, categorizing species based on their imminent threat of extinction. Can you crack the code of the Red List and predict which species might vanish within the next 50 years? What emergency measures could be taken to prevent their disappearance and ensure a future where all species can thrive?

- **Role of United Nations Development Programme (UNDP):**
  - **Sustainable Development Goals:** UNDP plays a central role in supporting countries in achieving the Sustainable Development Goals (SDGs), particularly SDG 15: "Life on Land."
  - **Biodiversity and Development Nexus:** UNDP recognizes that biodiversity loss poses a significant threat to development, impacting food security, water resources, livelihoods, and disaster risk reduction. Its interventions in this area focus on:
    - Integrating biodiversity conservation into national development strategies and planning processes.
    - Supporting the development of nature-based solutions for addressing challenges like climate change and disaster risk reduction.
    - Building capacity of local communities to manage their natural resources sustainably.
    - Promoting access to finance and technology for biodiversity conservation and sustainable development.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is an independent intergovernmental body established to improve the science-policy interface for biodiversity and ecosystem services. It was established in Panama City on April 21, 2012, by 94 governments and is headquartered in Bonn,Germany.

- It is not a United Nations body. However, at the request of the IPBES Plenary and with the authorization of the UNEP Governing Council in 2013, the United Nations Environment Programme (UNEP) provides secretariat services to IPBES.

The Organization's Work Program Covers a Wide Range of Topics, Including

- The assessment of the status and trends of biodiversity and ecosystem services.
- The identification of the drivers of change affecting biodiversity and ecosystem services.
- The development of tools and methods to support the conservation and sustainable use of biodiversity and ecosystem services.
- The capacity building for the implementation of the IPBES work program.

IPBES has Produced a Number of Important Reports, Including

- The Global Assessment Report on Biodiversity and Ecosystem Services.
- The Assessment Report on Pollinators, Pollination and Food Production.
- The Assessment Report on Land Degradation and Restoration.

Restoration Barometer Report 2022

The International Union for Conservation of Nature (IUCN) has released its first Restoration Barometer Report. The report outlines investments totaling $26bn billion across 18 countries across Latin America, Africa, Asia, and Europe, Central Asia, and the Caucasus, have restored 14 million hectares of degraded landscapes. This area is roughly the size of Greece.

- The Restoration Barometer was originally launched in 2016 as the Bonn Challenge Barometer.
- Initially piloted in forest landscapes, it measured the success of restoration programs.
- Endorsed by over 50 countries, the tool was rebranded as the Restoration Barometer in 2020, extending its scope beyond forest ecosystems.
- **It tracks restoration efforts across all terrestrial ecosystem types, including coastal and inland waters.**
- It is the only tool used by governments to track restoration and its benefits across all terrestrial ecosystems.

International Cooperation: The Restoration Barometer is endorsed by over 50 governments and developed by the IUCN with support from the German Federal Ministry for the Environment.

These agreements, treaties, organizations, and NGOs represent a collective effort to address the complex and urgent challenges of biodiversity conservation on a global scale. As the world faces increasing threats to biodiversity, the collaboration and commitment of nations and organizations become increasingly crucial to ensure a sustainable and biodiverse future.

Gene Pool Centre

- The gene pool of a particular population is defined as the amalgamation of all genes within that population, encompassing the entirety of genetic diversity present in the population or species. Gene pool centers denote geographical locations where significant crop plants and domestic animals originated.
- These areas showcase a remarkable diversity of wild counterparts to cultivated plants and beneficial tropical plants. Additionally, gene pool centers harbor various species from sub-tropical and temperate regions.
- **Major Gene Centres:** There are seven major gene pool centres of agriculture in the world as mentioned below along with their location and types of crops which originated from them.

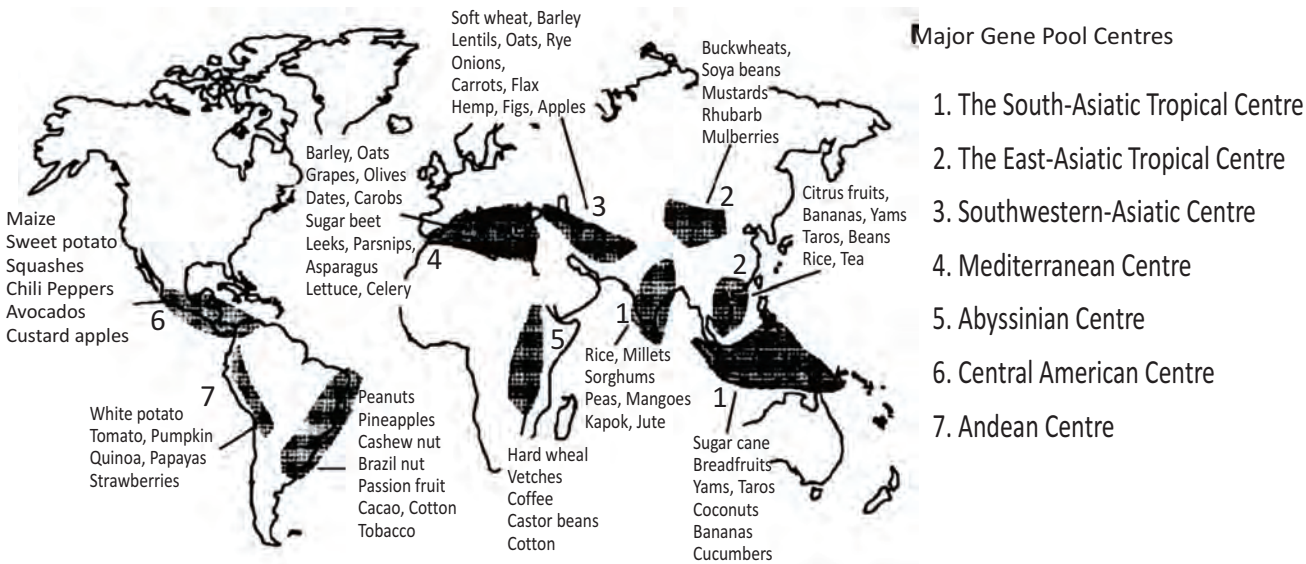


Fig. 6.7: Major Gene Pool Centres

Importance of Preserving Gene Pool

Preserving the gene pool is important for maintaining the genetic diversity and adaptability of populations, especially in the face of environmental changes, diseases, and other threats.

- A diverse gene pool ensures the presence of a wide range of alleles that can confer beneficial traits or resistance to stresses. A narrow gene pool, on the other hand, increases the risk of genetic diseases, deformities, and extinction.
- According to FAO, about 75 percent of crop genetic diversity was lost in the last century as farmers switched to genetically uniform varieties. This reduces the potential of developing new and improved crop varieties that can cope with changing climate and pests.

Gene Pool Preservation Benefits

- **Species Survival and Adaptation:**
  - **Genetic Diversity:** Wide range of traits aids adaptation to environmental changes and disease resistance.
  - **Evolutionary Potential:** Ensures persistence of beneficial mutations for continual adaptation.
- **Ecosystem Health and Function:**
  - **Community Resilience:** Maintains stability by fostering interactions within ecosystems.
  - **Food Web Stability:** Prevents predator specialization, ensuring ecological balance.

Future Advancements

- Agriculture and Food Security: Wild crop relatives offer genes for resilient crops.
- Medicine and Drug Discovery: Unique genetic variations may lead to new treatments.
- Biotechnology and Sustainability: Diverse gene pools drive innovations for environmental challenges.

Therefore, conserving gene pool is essential for the survival and well-being of both humans and other living organisms.

ROLE OF TRADITIONAL KNOWLEDGE IN CONSERVATION MEASURES

Traditional knowledge conservation measures play a crucial role in preserving the vast and irreplaceable wisdom of indigenous and local communities around the world. This knowledge encompasses a wealth of information on various aspects of life, including:

- **Biodiversity and natural resource management:** Traditional communities have accumulated centuries of knowledge about sustainable practices for managing ecosystems, using natural resources, and protecting endangered species.
  - This knowledge can inform conservation efforts and contribute to the development of more effective strategies.
- **Cultural identity and heritage:** Traditional knowledge is deeply intertwined with the cultural identity and heritage of indigenous and local communities. It reflects their unique relationship with the environment, their spiritual beliefs, and their social values.
  - Conserving this knowledge helps safeguard cultural diversity and promotes intergenerational transmission of valuable traditions.
  - The **Warli tribe** in Maharashtra has a rich tradition of creating intricate paintings depicting their close connection with nature. These paintings not only showcase their artistic skills but also convey their spiritual beliefs and social values.
- **Food security and agriculture:** Traditional knowledge systems often hold valuable insights into sustainable agricultural practices, crop varieties, and food preservation techniques.
  - This knowledge can contribute to enhancing food security and promoting sustainable food production methods.
  - The traditional rice-fish farming systems in Kerala are an excellent example. Here, farmers grow rice and fish together in the same fields, following age-old practices.
- **Climate change adaptation and disaster risk reduction:** Indigenous communities have often developed sophisticated strategies for adapting to changing environmental conditions and mitigating the impacts of natural disasters.
  - Their knowledge can be crucial for building resilience in the face of climate change and other environmental challenges.
  - The Ladakhi people in the Himalayan region have developed innovative water management systems known as "ice stupas." During the winter, they create artificial glaciers by diverting and freezing water. In the spring, these ice stupas slowly melt, providing a controlled release of water for crops.

Some of the key measures that can be taken to conserve traditional knowledge:

- **Documentation and archiving:** Recording traditional knowledge through various means, such as oral histories, written documentation, and audio-visual recordings, is essential for preserving it for future generations.
- **Community-based initiatives:** Supporting and empowering indigenous and local communities to manage their own knowledge systems and share their knowledge with others is crucial for ensuring its long-term sustainability.
- **Education and awareness raising:** Raising awareness about the value of traditional knowledge and integrating it into educational systems can help foster respect for indigenous cultures and promote its wider application.
- **Intellectual property protection:** Developing mechanisms to protect the intellectual property rights of indigenous communities over their traditional knowledge is essential to prevent its misappropriation and exploitation.

Traditional Knowledge Conservation Measures in India

1. **People's Biodiversity Registers (PBRs):**
   - Implemented through local governing bodies, PBRs document and maintain records of various forms of traditional knowledge, including:
     - Medicinal plants and their uses
     - Indigenous agricultural practices
     - Folk varieties of crops and livestock
     - Conservation techniques for local biodiversity
2. **Traditional Knowledge Digital Library (TKDL):**
   - This online platform, established by the Government of India, stores and disseminates information on traditional knowledge related to:
     - Ayurveda, Unani, Siddha, and Yoga (traditional Indian medical systems)
     - Medicinal plants and their formulations
     - Traditional ecological knowledge
3. **Community-based conservation initiatives:**
   - Numerous NGOs and research institutions collaborate with indigenous communities to document and utilize their knowledge for conservation purposes.
     - For example, the Kani tribe in Kerala shared their knowledge of the "Arogyapaacha" plant with scientists, leading to the development of the anti-diabetic drug "Jeevani."
4. **Integration into educational systems:**
   - Some universities and educational institutions are incorporating traditional knowledge into their curriculum, particularly in fields like agriculture, medicine, and environmental science.
5. **Intellectual Property protection:**
   - The Geographical Indications (GI) Act protects traditional knowledge associated with specific geographical locations and communities. Examples include GI tags for Darjeeling tea and Alphonso mangoes.

IGNITE YOUR MIND

Bridging the Knowledge Gap: Weaving Indigenous Wisdom into the Conservation Tapestry

Local communities often possess a treasure trove of knowledge about their ecosystems, passed down through generations. Explore how this traditional knowledge can be effectively integrated with scientific approaches to create a more holistic and successful conservation strategy. Imagine yourself as a scientist working alongside a local community. How can you bridge the cultural gap and ensure that your project addresses their needs while incorporating their invaluable knowledge?

Role of Tribes

Tribes in India have played a crucial role in biodiversity conservation for centuries. Their deep connection with nature, traditional practices, and belief systems contribute significantly to maintaining healthy ecosystems and protecting diverse species.

- The **Great Indian Bustard** is a critically endangered bird that lives in the grasslands and deserts of Rajasthan, Gujarat, and Maharashtra. It is revered by the Bishnoi tribe, who consider it a symbol of their faith and protect it from poachers.
- The **Red Panda** is a rare and adorable mammal that inhabits the temperate forests of Sikkim and Arunachal Pradesh. It is admired by the Lepcha tribe, who call it the "sacred bamboo cat" and believe it brings good luck.
- The **Neelakurinji** is a beautiful purple flower that blooms once in 12 years in the hills of Kerala and Tamil Nadu. It is cherished by the Kurumba tribe, who use it for medicinal purposes and as a source of honey.
- The **King Cobra** is the world's longest venomous snake that dwells in the dense forests of Kerala and Tamil Nadu. It is respected by the Irula tribe, who are expert snake catchers and venom extractors.
- The **tiger** is worshiped by the Chenchu tribe inhabiting the Nallamala Hills of Andhra Pradesh. They follow traditional practices that protect the forest and its inhabitants. Believing that harming tigers brings misfortune, the Chenchus actively participate in tiger conservation programs.
- The **goats** share a unique relationship with the **Gaddi Tribe** which is found in the Jammu and Kashmir and regions of Himachal Pradesh. The Gaddi tribe is known for its unique relationship with goats.
  - They raise goats while adhering to sustainable grazing practices, protecting the fragile mountain ecosystems. Additionally, the Gaddis worship nature deities and safeguard forests from deforestation.
- The **Snow Leopard** is a majestic and elusive cat that roams the high-altitude regions of Ladakh, Himachal Pradesh, Uttarakhand, and Sikkim. It is respected by the Bhotia and Ladakhi tribes, who coexist with it in harmony.

ROLE OF NGOS IN BIODIVERSITY CONSERVATION

Numerous national and international NGOs play a crucial role in biodiversity conservation worldwide.

International NGOs

- **World Wildlife Fund (WWF):** A global leader in conservation, WWF focuses on protecting endangered species, conserving habitats, and promoting sustainable practices. They work in various countries, including India, on projects like tiger conservation and combating illegal wildlife trade.
- **The Nature Conservancy:** This organization focuses on land and water conservation, protecting critical habitats and endangered species around the world. They have projects in India aimed at conserving forest corridors and marine ecosystems.
- **International Union for Conservation of Nature (IUCN):** A global network of governments, NGOs, and scientists, IUCN sets the global conservation agenda through policy recommendations, scientific data, and conservation projects. They work in India on various issues like protected area management and species conservation.
- **BirdLife International:** This global partnership focuses on the conservation of birds and their habitats. They work in India on projects like protecting migratory birds and conserving important bird areas. It identifies the sites known as 'Important Bird and Biodiversity Areas'.

NGOs in India

- **Wildlife Trust of India (WTI):** A leading Indian NGO, WTI works on various conservation issues like tiger conservation, elephant protection, and habitat restoration. They have played a significant role in raising awareness and advocating for policy changes in India.
- **Bombay Natural History Society (BNHS):** One of the oldest conservation organizations in India, BNHS focuses on research, education, and conservation projects related to birds, mammals, and other wildlife. They have contributed significantly to documenting India's biodiversity and promoting conservation awareness. It is headquartered in Mumbai and was founded in 1883.
- **Centre for Environmental Education (CEE):** This national organization focuses on environmental education and awareness raising. They work with various stakeholders, including schools, communities, and policymakers, to promote sustainable practices and biodiversity conservation.

- **Kalpavriksh:** This environmental NGO works on various issues related to biodiversity conservation, environmental policy, and community development. They have been actively involved in advocating for sustainable forest management and protecting indigenous rights.

IGNITE YOUR MIND

The Ripple Effect: Your Actions Matter More Than You Think

Even the smallest actions can create a ripple effect. Discover how individuals, through their choices and participation in conservation initiatives, can contribute to protecting the planet's biodiversity. If everyone on Earth took one small action for conservation every day, what collective impact could we achieve? Imagine the possibilities!

Wildlife Trust of India

The Wildlife Trust of India (WTI) is a leading Indian non-profit organization dedicated to wildlife conservation. Founded in 1998, WTI works to conserve India's diverse wildlife and their habitats through a variety of programs and initiatives.

Mission and Vision

WTI's mission is to "conserve wildlife and its habitat, and to work for the welfare of individual wild animals, in partnership with communities and governments." The organization's vision is to "see a world where wildlife and wild places flourish, and where humans live in harmony with nature."

Key Areas of Focus

- **Wildlife crime prevention:** WTI works to combat wildlife poaching and trafficking through anti-poaching patrols, wildlife rescue and rehabilitation, and education and awareness programs.
- **Species recovery:** WTI focuses on the conservation of endangered and threatened species, such as tigers, elephants, and rhinos.
- **Habitat protection:** WTI works to protect critical wildlife habitats, such as forests, grasslands, and wetlands.
- **Human-wildlife conflict mitigation:** WTI works to reduce conflict between humans and wildlife through education, awareness programs, and community-based initiatives.

Achievements

WTI has made significant contributions to wildlife conservation in India over the past two decades. Some of its key achievements include:

- Establishing India's first wildlife crime helpline.
- Rescuing and rehabilitating thousands of wild animals.
- Protecting critical wildlife habitats.
- Educating and empowering local communities to conserve wildlife.

In a world confronting environmental challenges, NGOs play a vital and indispensable role in fostering a sustainable and harmonious relationship between humanity and the natural world.

Through advocacy, community engagement, research, and international collaboration, they contribute to ecosystem resilience, protect endangered species, and ensure the well-being of current and future generations.

SPECIES SPECIFIC CONSERVATION INITIATIVES

Tiger

The Indian Tiger, also known as the Royal Bengal Tiger (Panthera tigris), is a significant species with distinct characteristics and conservation status.

Fig. 6.8: The Royal Bengal Tiger

- **Physical Characteristics:**
  - The tiger (Panthera tigris) is the largest extant cat species and a member of the genus Panthera.
  - Recognizable for dark vertical stripes on orange-brown fur with a lighter underside.
  - Apex predator, primarily preying on ungulates like deer and wild boar.
  - Territorial and generally solitary but requires large contiguous areas of habitat.
- **Habitat:**
  - Bengal tiger habitats include tropical rainforests, marshes, and tall grasses.
- **Global Population:**
  - India is home to almost 75% of the global tiger population.
  - Other populations exist in Bangladesh, Nepal, Bhutan, and potentially China and Burma.
- **Conservation Status:**
  - **IUCN Red List:** Endangered
  - **Wildlife Protection Act:** Schedule I
  - **CITES:** Appendix I
- **Threats to Tigers in India:**
  - Habitat loss
  - Human-wildlife conflict
  - Poaching and wildlife crime

Conservation Efforts in India

Project Tiger:

Project Tiger, launched in 1973, is a flagship conservation program in India aimed at protecting the endangered Bengal tiger. The National Tiger Conservation Authority (NTCA) provides statutory authority to Project Tiger so that compliance of its directives become legal.

Objectives:

- **Reverse the declining population of Bengal tigers:** From an estimated 4,000 tigers in 1965 their numbers dwindled to a mere 1,827 in 1972 due to poaching, habitat loss, and human-wildlife conflict. Project Tiger aimed to reverse this trend.
- **Establish tiger reserves:** Dedicated protected areas with strict conservation measures to provide safe havens for tigers and their prey.
- **Empower local communities:** Promote community participation in conservation efforts and address their concerns through eco-development initiatives.

Achievements

- **Increased tiger population:** The 2022 tiger census estimated a national population of 3,682 (average) with minimum population of 3,167 and upper limit of 3,925. tigers, marking a significant increase from 2010 and achieving the ambitious goal of doubling the tiger population from 2000.
- **Established tiger reserves:** Currently, there are 54 tiger reserves across 18 tiger states, encompassing over 78,135.956 sq. km of habitat.
- **Enhanced anti-poaching measures:** Increased patrolling, improved intelligence gathering, and stricter enforcement laws have helped curb poaching activities.
- **Community involvement:** Eco-development programs have provided alternative livelihoods for communities dependent on forest resources, fostering a sense of ownership and partnership in conservation.

Fig. 6.9: Achievements of Project Tiger

Tiger Census 2022

- **Total Tiger Population:**
  - The tiger occupancy has increased from 1758 cells of 100 km2 in 2018 to 1792 in 2022. The unique tigers photographed in 2022 is 3080, while in 2018 there were 2461 unique tigers captured. The minimum estimated population is 3167.
  - This indicates a growth of 200 tigers over the four-year period.
  - The largest tiger population of 785 is in Madhya Pradesh, followed by Karnataka (563) & Uttarakhand (560), and Maharashtra (444).
  - The tiger abundance within the Tiger Reserve is highest in Corbett (260), followed by Bandipur (150), Nagarhole (141), Bandhavgarh (135), and Dudhwa (135).
- **Growth Rate:**
  - The growth rate has slowed to 6.7% during 2018-2022, a significant decrease from the approximately 33% growth observed during 2014-2018.
- **Regional Changes:**
  - **Increase:**
    - Significant growth in tiger population observed in the Shivalik Hills and Gangetic Plains.
    - The North East Hills and Brahmaputra Plains, particularly the Nilgiri cluster, are highlighted as the largest tiger population in the world.
  - **Decline:**
    - Tiger occupancy in the Western Ghats declined, especially in the Wayanad landscape and the Biligiriranga Hills.
- **Geographical Insights:**
  - Camera traps documented 194 tigers in the North East Hills and Brahmaputra Plains. Notably, tiger occupancy in Jharkhand, Odisha, Chhattisgarh, and Telangana showed signs of decline.
- **Prioritizing Conservation:**
  - The small and genetically distinct tiger population in Simlipal is recognized as a top conservation priority.
- **Strategies for Conservation:**
  - Promoting economically sustainable development with ecological viability is a key conservation emphasis. Additionally, implementing trans-boundary tiger conservation strategies is essential for sustaining isolated populations.

Tiger Census Methodologies in India

- **Field Surveys:** Conducted by trained forest department staff, wildlife biologists, and conservation organizations with local community collaboration.
- **Camera Trapping:** Utilized widely across tiger habitats in national parks, wildlife sanctuaries, and reserves, capturing images for population estimation and individual identification.
- **Genetic Analysis:** Increasingly used to estimate population size, genetic diversity, and relatedness through analysis of scat, hair, and tissue samples.
- **Statistical Modeling:** Population estimates analyzed using statistical models to assess size, density, and trends over time.

- Collaboration and Coordination: Involves various stakeholders such as government agencies, NGOs, and research institutions.
- Validation and Peer Review: Results undergo validation and peer review by independent experts and international organizations.

mStripes

mSTrIPES, which stands for Monitoring System for Tigers - Intensive Protection and Ecological Status, is a software-based monitoring system launched across Indian tiger reserves by the Indian government's National Tiger Conservation Authority (NTCA) in 2010.

Objectives

- Strengthen patrolling and surveillance.
- Improve data collection and analysis.
- Promote habitat conservation.

Tiger Reserves

Tiger reserves are protected areas designated for the conservation of the striped big cats (tigers) and their habitats in India. They are governed under Project Tiger, which is administered by the National Tiger Conservation Authority, Government of India.

- As of 2023, there are 54 tiger reserves in India, covering a total area of more than 78,000 Square KM. Some of the most famous tiger reserves in India are Corbett (Uttarakhand), Ranthambore (Rajasthan), Bandipur (Karnataka), Kanha (Madhya Pradesh), Periyar (Kerala), and Sundarban (West Bengal).
- India is home to 80 percent of tigers in the world, and has more than doubled its tiger population from 1,411 in 2006 to 3,167 in 2022 This is a remarkable achievement for the country and the global efforts to save the endangered species.

Recently added Tiger Reserves:

- Ramgarh Vishdhari Tiger Reserve - Rajasthan
- Ranipur Tiger Reserve - Uttar Pradesh
- Veerangana Durgavati Tiger Reserve - Madhya Pradesh
- Dholpur – Karauli Tiger Reserve - Rajasthan

Global Tiger Conservation Initiatives

- **Global Tiger Initiative (GTI):**
  - A global alliance involving governments, international organizations, civil society, and the private sector.
  - Led by the 13 tiger range countries, it aims to save wild tigers from extinction.
  - Expanded in 2013 to include Snow Leopards.
  - TX2 Goal: In 2010, the **St. Petersburg Declaration** on Tiger Conservation was adopted, endorsing the goal to double the number of wild tigers across their geographical areas. Implemented by WWF in 13 tiger range countries.
- **Conservation Assured (CA|TS):**
  - A management tool setting criteria for effective conservation in tiger reserves.
  - Based on seven pillars with 17 minimum standards, addressing various conservation factors.
  - Driven by the CA|TS Partnership, comprising tiger range governments, intergovernmental agencies, and conservation organizations.
  - Key in achieving the goal of doubling the global tiger population by 2022.
- **Integrated Tiger Habitat Conservation Programme (ITHCP):**
  - A strategic funding mechanism supported by the German Government and KfW (German Development Bank).
  - Launched in 2014 to save tigers, their habitats, and support human populations in key Asian locations.
  - Aligns with the international goal set during the 2010 St. Petersburg Tiger Summit to double wild tiger populations by 2022.
  - Implemented by IUCN.
- **Global Tiger Forum (GTF):**
  - The only inter-governmental international body formed in 1994 to protect tigers globally.
  - Members from willing countries work together on a global campaign for tiger conservation.
  - Headed by a Chairperson from one of the Tiger Range countries for a fixed tenure of 3 years.
  - The Secretariat is located in New Delhi, India.
- **Global Tiger Recovery Program (GTRP):**
  - Aims to empower Tiger Range Countries to address threats, both domestic and trans-boundary.
  - Focuses on increased financial sustainability through the integration of conservation objectives into development.
- **TX2:**

  TX2 stands for "Tigers times two". It's a global goal set by the World Wildlife Fund (WWF) to double the number of wild tigers by 2022.
  - In 2010, the 13 countries that have tiger ranges committed to doubling the number of wild tigers by 2022. In 2010, the tiger population was at an all-time low of 3,200, down from a population of about 100,000 a century ago.
  - TX2 is the largest undertaking ever for the conservation of a single species, working across governments, communities, and habitats.
- **International Big Cat Alliance (IBCA):**

  The International Big Cat Alliance (IBCA), launched by Hon'ble Prime Minister of India Shri Narendra Modi aims to strengthen global cooperation and efforts for conservation of seven big cat species (tiger, lion, leopard, snow leopard, cheetah, jaguar and puma) and their habitats.

- The alliance will focus on the protection of seven major cat species and work with countries harbouring these big cats to stop the illegal wildlife trade.
- The global bloc will include as many as 97 range countries.
- However, unlike the Global Tiger Forum, it will work towards the conservation of natural habitats of the other big cats, along with the tiger Its headquarter is to be established in New Delhi.

Elephant

Elephants belong to the family Elephantidae and are the largest existing land animals. Three recognized species are the African bush elephant, African forest elephant, and Asian elephant. The leader of an elephant group is the oldest female. She leads the group in search of food and water. The gestation period of the breeding pair is nearly 22 months which yields a single baby. During birth, females of the herd surround the mother for her protection. The average life expectancy of an elephant is 70 years and at the age of 18 years, its adulthood starts.

- **Distribution:** Elephants are found throughout sub-Saharan Africa, South Asia, and Southeast Asia. They inhabit diverse ecosystems, including savannahs, forests, deserts, and marshes. Elephants are considered keystone species due to their significant impact on their environments. In India, Elephants are found in four fragmented populations in the south, north, central and northeast India. Habitat ranges from wet tropical evergreen forests to semi-arid thorn and scrub forests. However, the highest densities of the elephant population are found in tropical deciduous forests. Elephants are 'mega-herbivores' that require vast tracts of forests and grasslands rich in food and water to survive. According to Elephant Census (2017), Karnataka has the highest number of elephants (6,049), followed by Assam (5,719) and Kerala (3,054).
- **Conservation Status:**
  - **African Forest Elephants:** Critically Endangered (IUCN Red List).
  - **African Savanna Elephants:** Endangered (IUCN Red List).
  - **Asian Elephants:** Endangered (IUCN Red List).
  - Protected under Schedule I of the Wildlife Protection Act and listed under Appendix I of CITES.
- **Threats:**
  - Ivory trade poses a significant threat, leading to poaching for tusks.
  - Habitat destruction and conflicts with local communities are additional challenges.
- **National Heritage Animal:** The elephant is designated as the National Heritage Animal of India.
- **Population in India:** India hosts over 60% of the global Asian elephant population.

Conservation Efforts in India

- **Project Elephant (1992):**
  - A Centrally Sponsored Scheme focusing on elephant conservation.
  - Objectives include protecting elephants, their habitat, addressing man-animal conflicts, and ensuring the welfare of captive elephants.
  - Measures include protection from poaching, inter-state coordination, infrastructure development, research, and disease prevention.
- **Elephant Corridors:**
  - Narrow strips of land facilitating elephant movement between habitat patches.
  - Government initiatives involve voluntary relocation, land acquisition, and protection measures for corridors.
  - Approximately 100 elephant corridors identified; steps include financial assistance, habitat improvement, patrolling, training, and eco-restoration.

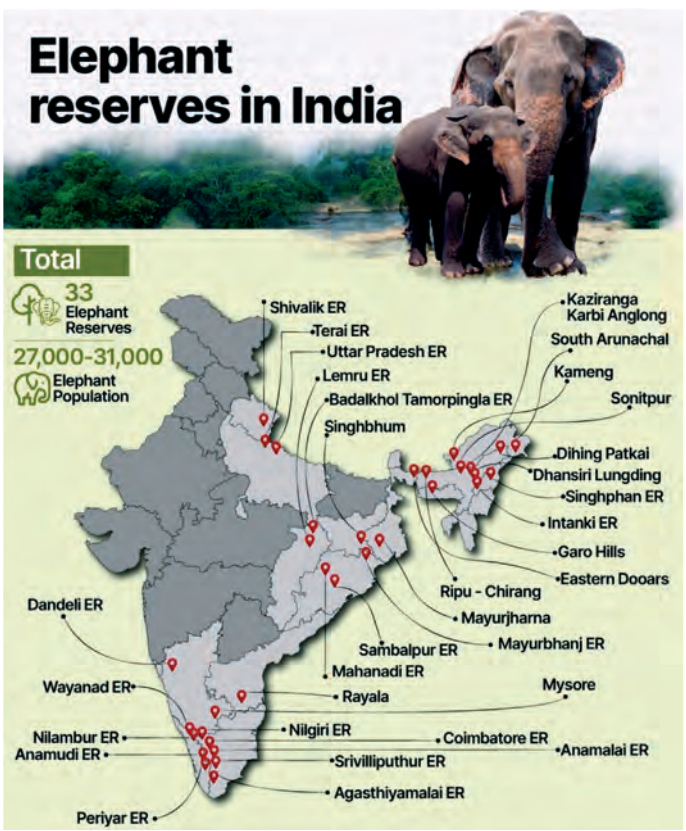


Fig. 6.10: Elephant Reserves in India

Initiatives

- **Hathi Mere Saathi:**
  - The Government of India launched the Hathi Mere Sathi campaign at the Elephant-8 ministerial meeting in New Delhi in 2011.
  - This campaign was started by the Ministry of Environment and Forests (MoEF) in collaboration with Wildlife Trust of India (WTI).

- The aim of this campaign is to raise awareness about the challenges related to elephants and work for their protection and conservation.
- World Elephant Day is celebrated on 12 August. The purpose of this day is to increase awareness about the challenges related to elephants and to work for their safety and conservation.

❑ **Gaj Yatra:**
- Gaj Yatra is a nationwide campaign for the conservation of elephants. Its objective is to spread awareness in 12 states having abundance of elephants. Under this campaign, 100 elephant corridors are to be protected in India.
- The Ministry of Environment, Forest and Climate Change had started the Gaj Yatra from Tura village in the Garo Hills on May 28, 2018. This campaign was organized by Wildlife Trust of India (WTI) in collaboration with the Environment Ministry.
  - ❒ It is partnered by the International Fund for Animal Welfare (IFAW).

Global Efforts

❑ **Monitoring of Illegal Killing of Elephants (MIKE) Programme:**
- Established by CITES to monitor illegal killing trends in elephants across Africa and Asia.
- International collaboration to assess the effectiveness of conservation efforts.
- India has ten sites under the MIKE programme.

❑ **Asian Elephant Alliance (2015):**
- An alliance of five NGOs, aiming to secure a safe future for the world's wild Asian elephants, with a focus on India.

❑ **Elephant Trade Information System (ETIS):**
- Established in 1989 to analyze illegal trade in ivory and other elephant products.
- Managed by TRAFFIC.
- Tracks and records serial numbers of tusks to control and monitor global ivory trade.

❑ **E-50:50 Forum:** It is a shared vision of 50 states to promote the conservation, management, and welfare of elephants in the next 50 years.
- The E-8 countries hold this forum to adopt a common global vision for conservation, management, and welfare of elephants across all range countries.
  - ❒ **E-8 country:** Botswana, Congo, India, Indonesia, Kenya, Sri Lanka,Thailand,United Republic of Tanzania.

Snow Leopard

❑ **Population Estimate:** Estimated at 400 to 700 individuals in five Himalayan states in India. They are among the most endangered large cats.

Fig. 6.11: The Snow Leopard

❑ **Habitat:** Snow leopards inhabit mountainous regions of central and southern Asia. In India, they are found in the western Himalayas, including states like Jammu and Kashmir (erstwhile) Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh in the eastern Himalayas.

❑ **Threats:**
- Reduction in prey populations.
- Illegal poaching.
- Human population infiltration into their habitat.
- Illegal wildlife trade, including trade in parts and products.

❑ **Conservation Status:**
- **IUCN Red List:** Vulnerable
- **CITES:** Appendix I
- **CMS (Convention on Migratory Species):** Appendix I
- **Wildlife (Protection) Act 1972:** Schedule I

Conservation Efforts in India

❑ **Project Snow Leopard (2009):**
- Launched to conserve snow leopards and their habitat.
- Emphasizes knowledge-based, landscape-level, and participatory management.
- Range states identify landscapes, conduct surveys, and involve communities in minimizing human use in identified cores.
- Village cluster to central-level representation is included.

❑ **SECURE Himalaya (2017-2023):**
- A Government of India (MoEFCC)-UNDP-GEF project implemented in Jammu & Kashmir, Himachal Pradesh, Uttarakhand, and Sikkim.
- Aims to demonstrate best practices for high range Himalayan ecosystem and snow leopard conservation, with a focus on scaling up nationally and globally.
- Focal species: Snow Leopard.

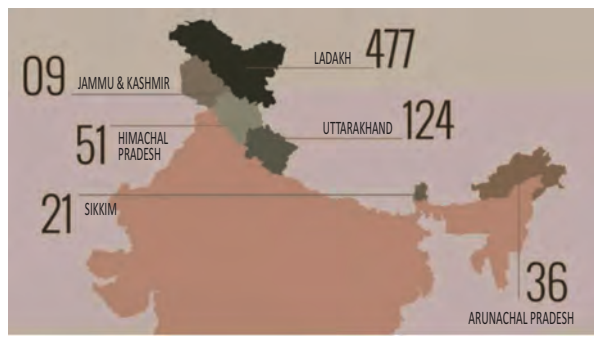


Fig. 6.12: Snow Leopard Population

Snow Leopard Population Assessment in India (SLPAI)

- Prepared by various organizations.
- A protocol for national-level estimation processes similar to Tigers, Rhinos, and Elephants.
- Challenges include sampling only 2% of snow leopard habitats due to difficult terrain and elusive nature.

Global Efforts

- **Global Snow Leopard and Ecosystem Program (GSLEP):**
  - An intergovernmental alliance of 12 Snow Leopard range countries (Afghanistan, Bhutan, China, India, Kazakhstan, Kyrgyz Republic, Mongolia, Nepal, Pakistan, Russia, Tajikistan, and Uzbekistan).
  - Unites governments, NGOs, local communities, and the private sector.
  - Aims to conserve snow leopards and their high-mountain ecosystems.

The Padmaja Naidu Himalayan Zoological Park (PNHZP), located in West Bengal and commonly referred to as Darjeeling Zoo, has garnered international acclaim from the World Association for Zoos and Aquariums (WAZA) for its effective conservation breeding program (CBC) focused on snow leopards. Notably, Darjeeling Zoo stands as India's largest high-altitude zoo.

Asiatic Lion

- **Distribution in India:** Asiatic lion, once ranged from Iran to Palamau in Eastern India, is now naturally found in India only. Limited to five protected areas in Gujarat – Gir National Park, Gir Sanctuary, Pania Sanctuary, Mitiyala Sanctuary, and Girnar Sanctuary. An MoEFC's expert committee has approved Kuno Palpur Wildlife Sanctuary in Madhya Pradesh as a second home for Asiatic lion.

PRIDE PROTECTION
The broad goals of Project Lion include averting the risk of extinction of Asiatic lions
Another aim is to secure and manage lion habitat on a sustainable basis
The geographical coverage of the project includes Gir Protected Areas and Girnar Wildlife Sanctuary
Other areas in the project are lion corridors (riverine and non-riverine) including government wa stelands and gauchar lands

Fig. 6.13: Pride Project

- **Conservation Status:**
  - **IUCN Red List:** Endangered
  - **Wildlife (Protection) Act:** Schedule I
  - **CITES:** Appendix I
- **Comparison with African Lions:**
  - **Size:** Asiatic lions tend to be smaller.
  - **Mane:** The male Asiatic lion has a relatively short, sparse, and darker mane compared to African lions. The ears of the male Asiatic lion are typically visible at all times.
  - **Skin Fold:** Asiatic lions have a longitudinal fold of skin along the belly, absent in African lions.
  - **Pride Size:** Asiatic prides are generally smaller.
  - **Threats:** Habitat loss, Poaching, Human-wildlife conflict, Disease, Climate change, Inbreeding

Project Lion (2021)

Project Lion is an initiative by the Indian government to conserve the Asiatic lion, a subspecies of lion that is only found in the Gir region of Gujarat. The project aims to secure and restore the lions' habitats, mitigate human-wildlife conflicts, enhance livelihoods of local communities, and create a global hub of knowledge on big cat conservation.

- Under Project Lion, the Gujarat government aims to establish a National Wildlife Disease Diagnostic Centre for a projected investment of Rs 71 crore.
- A lion cell at the Union Ministry of Environment, Forest and Climate Change is also envisioned for an investment of Rs 31.65 crore under the proposed plan.
- The Gujarat government has taken up the task of maintaining the health of the lions and their conservation by developing a new concept of an advanced lion hospital.
  - Other features are lion ambulance, rescue and rapid action team, trackers, and Vanyaprani Mitras in Sasan Gir with public participation.
- For breeding of lions, gene pools have been started at three places: Rampara in Saurashtra, and Sakkarbaug and Satveerada in Junagadh.

Asiatic Lion Conservation Project

- Launched by the Ministry of Environment, Forest and Climate Change.
- Funded under the Centrally Sponsored Scheme-Development of Wildlife Habitat (CSS-DWH) with a contributing ratio of 60:40 (Central and State share).
- **Focus:**
  - Habitat improvement.
  - Scientific interventions.
  - Disease control.
  - Veterinary care.
  - Eco-development works for the fringe population.

Methodology of Lion Census

While India employs several scientific methodologies for tiger census, the methodology for lion census in India differs slightly. Current Methodology used in lion census are as follows.

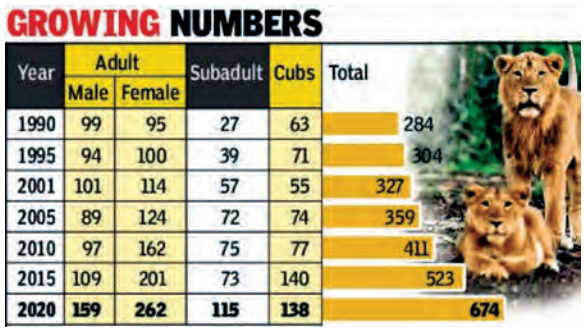


Fig. 6.14: Findings of Lion Census

- **Block Counting Method:** This is the primary method used for lion census in India, particularly in the Gir National Park, the sole habitat for Asiatic lions. It involves dividing the park into blocks and stationing enumerators at water points within each block during the summer. Lions must drink daily, so enumerators directly count all individuals encountered, estimating the abundance for each block. **This method is relatively simple and cost-effective but faces limitations:**
  - **Accuracy:** Relies on visual sightings at water points, potentially missing lions elsewhere or double-counting those using multiple points.
  - **Seasonality:** Limited to summer when water dependence is high, not reflecting year-round population dynamics.
  - **Subjectivity:** Relies on observer skills and judgments, introducing potential bias.

Proposed Solution to Overcome these Limitations

- **Camera Trapping:** Similar to tiger census, using strategically placed cameras to capture images and identify individual lions based on whisker patterns. This improves accuracy and provides data on distribution and behavior. However, dense vegetation and camera costs pose challenges.
- **Spatially Explicit Capture-Recapture (SECR):** This statistical approach combines camera trapping data with sign surveys to estimate abundance, accounting for imperfect detection. While promising, it requires robust data and expertise for implementation.
- **Genetic Analysis:** Collecting and analyzing lion scat samples can reveal individual identities and population structure, offering insights beyond direct counts. However, it requires specialized techniques and interpretation.

One-Horned Rhino

Indian Rhinoceros:

- **Distribution:**
  - Native to the Indian subcontinent.
  - Found commonly in Nepal, Bhutan, Pakistan, and India.

Fig. 6.15: The Great Indian Rhinoceros

- India is home to 2,200 rhinos, constituting over 85% of the population.
- Rhinos in India are found in parts of Uttar Pradesh, West Bengal, and Assam.
- Assam has 91% of the total Rhino population in India, concentrated in Kaziranga National Park and Pobitora Wildlife Sanctuary.

- **Threats:**
  - Poaching.
  - Habitat destruction.
  - Flooding.
  - Human and livestock encroachment on the rhino's habitat.
- **Conservation Status:**
  - **IUCN Red List:** Vulnerable.
  - **Wildlife (Protection) Act:** Schedule I.
  - **CITES:** Appendix I.

Conservation Efforts in India

- **Indian Rhino Vision 2020 (IRV 2020):**
  - Launched in 2005.
  - Aimed to achieve a wild population of at least 3,000 greater one-horned rhinos by 2020.

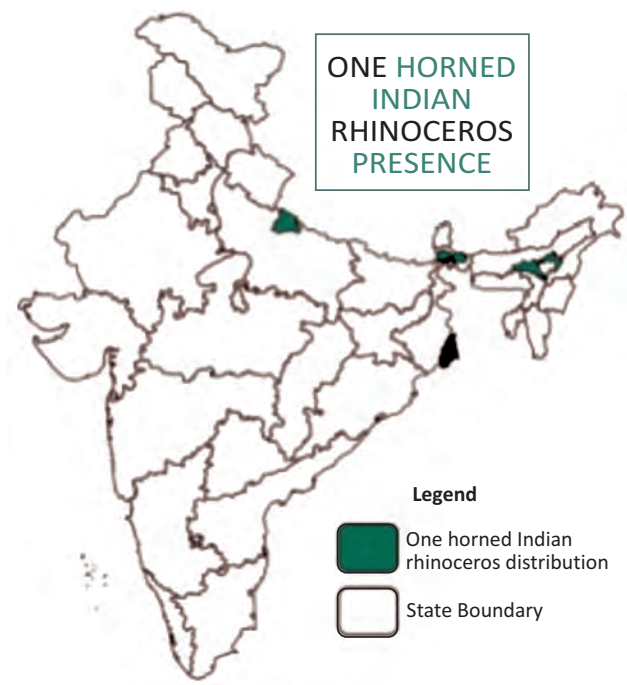


Fig. 6.16: Presence of Rhinoceros in India

  - Focus on translocating rhinos from Kaziranga National Park and Pobitora Wildlife Sanctuary to other protected areas in Assam (Manas, Laokhowa, Buracharpori-Kochmora, Dibrusaikhowa, and Orang).
  - Successful translocations have taken place, reducing the risk associated with having the entire rhino population concentrated in one specific area.

❑ **National Rhino Conservation Strategy (2019):**

- Aims to conserve the greater one-horned rhinoceros.
- Objectives include strengthening protection, expanding the distribution range, research and monitoring, and ensuring adequate and sustained funding.

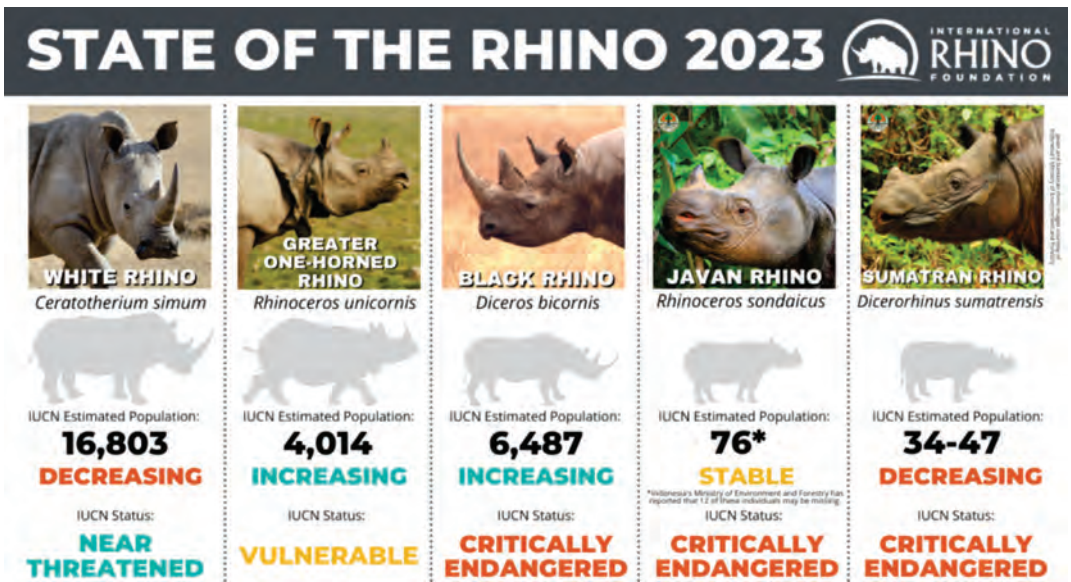


Fig. 6.17: State of the Rhino Report

❑ **DNA Profiling Project:**

- Initiated by the Ministry of Environment, Forest, and Climate Change (MoEFCC).
- Aims to create DNA profiles of all rhinos in the country.

Global Efforts for Rhino Conservation

❑ **WWF:** The World Wildlife Fund (WWF) has been working to protect the greater one-horned rhino since 1961. WWF supports anti-poaching patrols, habitat management, translocation, community engagement, and transboundary cooperation in India and Nepal.

❑ **ZSL:** The Zoological Society of London (ZSL) has been involved in greater one-horned rhino conservation since 1994. ZSL works with the government of Nepal and local partners to establish and train anti-poaching units, monitor rhino populations, and raise awareness among the public.

❑ **IRF:** The International Rhino Foundation (IRF) is a global organization dedicated to saving rhinos from extinction. IRF supported the Indian Rhino Vision 2020, a joint initiative of the government of Assam, WWF, and other partners to increase the rhino population and range in Assam by translocating rhinos from Kaziranga National Park to other protected areas.

Indian Ganges Dolphin

❑ **Distribution:**

- Inhabits the Ganges-Brahmaputra-Meghna and Karnaphuli-Sangu river systems in Nepal, India, and Bangladesh.
- One of the four freshwater dolphins globally, along with the baiji (Yangtze River, China), bhulan (Indus, Pakistan), and boto (Amazon River, Latin America).
- Fluviatile (riverine) in habitat but may also be found in brackish water.

Fig. 6.18: Gangetic Dolphin

❑ **Physical Characteristics:**

- Long thin snout, rounded belly, and large flippers.
- Requires surfacing every 30-120 seconds to breathe.
- Popularly referred to as 'Susu' due to the sound it produces when breathing.

❑ **Ecological Significance:**

- Acts as an indicator of a healthy ecosystem; its presence signifies greater biodiversity and helps maintain balance in the aquatic food chain.

❑ **Threats:**

- Severe threats from water development projects.
- Pollution.
- Hunting.
- Death due to accidental catches in fishing gear.
- Use of synthetic fertilizers and other agricultural chemicals in crop-fields in the vicinity of rivers

❑ **Conservation Status:**
- **IUCN Red List:** Endangered.
- **Wildlife (Protection) Act:** Schedule I.
- **CITES:** Appendix I.
- Designated as the national aquatic animal of India.
- Granted non-human personhood status by the government in 2017.

❑ **Conservation Efforts in India: Conservation Action Plan for Dolphins (2016):**
- Developed by the Wildlife Institute of India.
- Aims to develop a recovery plan for Ganges dolphins and their habitats in India.
- Involves stakeholders in the conservation of river ecosystems in India.
- Objectives include developing monitoring protocols, assessing the status of associated river fauna, evaluating river habitat quality, and addressing invasive species.

❑ **Other Conservation Efforts:**
- Conservation Action Plan for the Gangetic Dolphin 2010-2020 formulated by the Ministry of Environment, Forest and Climate Change.
- Recommendations include demarcating potential sites for intense dolphin conservation, establishing regional Dolphin Conservation Centres, banning harmful fishing practices, and determining critical water flow and minimum depths for dolphin habitats.
- National Mission for Clean Ganga (NMCG) works on Ganges River Dolphin Conservation Action.
- National Dolphin Research Centre (NDRC), Patna, focuses on strengthening conservation efforts and research for the endangered mammal.
- Vikramshila Gangetic Dolphin Sanctuary was established to protect endangered Gangetic dolphins.
  - ❒ It is located in Bhagalpur District of Bihar, India, and covers a 60 km stretch of the Ganges River from Sultanganj to Kahalgaon.
  - ❒ It was designated as a sanctuary in 1991 and named after the ancient Vikramshila University, a famous center of Buddhist learning.

Dugong

❑ **Description:**
- One of the four surviving species in the Order Sirenia.
- The only herbivorous mammal that exclusively lives in the sea.
- Feeds on seagrass.
- Can remain underwater for 3-12 minutes.
- Found in warm tropical waters.

Fig. 6.19: Dugong

- Distributed between East Africa and Vanuatu in the South Pacific Ocean.
- In India, it occurs in the Gulf of Mannar, Palk Bay, Gulf of Kutch, and Andaman and Nicobar Islands.
- Once abundant in Indian waters, the Dugong population has reduced to about 200 individuals, continuously declining in number and range.

❑ **Threats:**
- Despite legal protection in many countries, population decline is primarily anthropogenic.
- Threats include fishing-related fatalities, habitat degradation, and hunting.
- With a long lifespan of 70 years or more and a slow reproduction rate, Dugongs are especially vulnerable to extinction.

❑ **Conservation Status:**
- **IUCN Red List:** Vulnerable.
- **Wildlife (Protection) Act:** Schedule I.
- **CITES:** Appendix I.
- The Ministry of Environment, Forests and Climate Change has established a 'Task Force for Conservation of Dugongs' to address conservation issues and implement the 'UNEP/CMS Dugong MoU.'

❑ **National Conservation Plan:**
- Drafted for the conservation of Dugongs.
- **Includes species-level conservation and management:**
  - ❒ Assessing Dugong population status through advanced techniques.
  - ❒ Implementing site-specific monitoring plans to reduce hunting.
- **Habitat-level conservation and management:**
  - ❒ Reducing direct and indirect threats to seagrass habitat.
  - ❒ Improving habitat quality through a participatory approach.
- **Participatory management of Dugong and its habitats:**
  - ❒ Raising awareness through mobile campaigns and workshops.
  - ❒ Involving local communities and Dugong volunteer teams for long-term monitoring.
  - ❒ Encouraging critical habitat conservation by communities.
  - ❒ Establishing a network of 'Friends of Dugong' and 'Dugong scholarships.'
- **Capacity building of State Forest Departments and Local Communities:**
  - ❒ Undertaking underwater habitat monitoring and improving protection enforcement.
  - ❒ Creating a "Marine Rescue and Rehabilitation Team" at the state level.

❑ **Dugong Conservation reserve:**

- It is a protected area for the dugongs, also known as sea cows, and their marine habitats.
- India's first Dugong Conservation Reserve was established in September 2022, covering 448 sq. km of the coastal waters in Palk Bay, Tamil Nadu.
- The reserve aims to conserve the dugongs and the seagrass meadows they feed on, as well as other marine biodiversity such as otters, turtles, and seahorses.
- The reserve also supports the livelihoods of local fishermen and promotes eco-tourism.

Vultures

❑ **Description:**

- Scavenging birds of prey.
- Divided into New World vultures (Californian and Andean condors) and Old World vultures (White-rumped and Red-headed vultures).

Fig. 6.20: Indian Vulture

- New World vultures found in North and South America; Old World vultures found in Europe, Africa, and Asia.
- No vultures in Australia and Antarctica.
- Distinguishing characteristics include a bald head, devoid of normal feathers, and a feathery neck for hygiene and thermoregulation.
- Nine vulture species in India; five belong to the genus Gyps.
- Gyps vultures play a vital role in the ecosystem by cleaning up carcasses, specializing in feeding on the soft tissue of large ungulate carcasses.

India has 9 Species of Vultures

Indian Long-Billed Vulture (Gyps Indicus)

❑ **Description:** Smaller and less heavily built vulture species, breeds mainly on cliffs or human-made structures. Feeds mostly from carcasses of dead animals. Reached the verge of extinction due to the veterinary drug diclofenac.

❑ **Conservation Status (IUCN):** Critically Endangered.

Himalayan Vulture (Gyps Himalayensis)

❑ **Description:** One of the two largest Old World vultures, a true raptor, found along the Himalayas in India. The largest and heaviest bird found in the Himalayas of the Indian Subcontinent.

❑ **Conservation Status (IUCN):** Near Threatened.

Bearded Vulture (Gypaetus Barbatus)

❑ **Description:** Only member of the genus Gypaetus found in mountainous regions of the Himalayas and Ladakh in North India. Distributed from Kashmir to Arunachal Pradesh in the Indian subcontinent.

❑ **Conservation Status (IUCN):** Near Threatened.

Slender-Billed Vulture (Gyps Tenuirostris)

❑ **Description:** Critically endangered species of Old World vulture found along the Sub-Himalayan regions of the Indian subcontinent. Suffered an extremely rapid population decline, particularly across India.

❑ **Conservation Status (IUCN):** Critically Endangered.

White-Rumped Vulture (Gyps Bengalensis):

❑ **Description:** Medium-sized vulture, one of the most abundant large birds of prey globally. Smallest of the Gyps vultures found in India, the most common vulture in immense numbers.

❑ **Conservation Status (IUCN):** Critically Endangered.

Cinereous Vulture (Aegypius Monachus)

❑ **Description:** Large raptorial bird, a member of the family Accipitridae. Believed to be the largest true bird of prey in the world. Found in northern India.

❑ **Conservation Status (IUCN):** Near Threatened.

Egyptian Vulture (Neophron Percnopterus)

❑ **Description:** Widely distributed species of small Old World vulture found in the northwest part of India. Three widely-recognized subspecies are found in the Indian subcontinent.

❑ **Conservation Status (IUCN):** Endangered.

Red-Headed Vulture (Sarcogyps Calvus)

❑ **Description:** Also known as the Indian Black Vulture, found only in the Indian subcontinent. Medium-sized vulture with no subspecies, found in deciduous forests, foothills, and river valleys.

❑ **Conservation Status (IUCN):** Critically Endangered.

❑ **Population Decline:**

- Gyps vulture populations in the Indian subcontinent crashed since the 1990s.
- White-rumped Vulture, Long-billed Vulture, and Slender-billed Vulture populations declined by around 97% in the last two decades.
- Veterinary use of the drug 'diclofenac' is the main cause of population decline.
- The Government of India banned diclofenac in veterinary medicine and initiated the Vulture Breeding Programme for conservation.

Conservation Efforts in India

❑ **Vulture Conservation and Breeding Centre, Pinjore:**

- Joint project of Haryana Forest Department and the Bombay Natural History Society (BNHS).
- Established to save White-backed, Long-billed, and Slender-billed vultures from extinction.
- Funded by the UK Government's 'Darwin Initiative for the Survival of Species.'
- Designated as the Coordinating Zoo for Vulture Conservation in India by the Central Zoo Authority.

- **Vulture Conservation Project 2020-2025:**
  - Action Plan for Vulture Conservation.
  - Uttar Pradesh, Tripura, Maharashtra, Karnataka, and Tamil Nadu to get vulture conservation and breeding centres.
  - Strategies for ex-situ and in-situ conservation.
  - Testing new veterinary drugs on vultures before commercial release.
  - Automatic removal of toxic drugs from veterinary use.
  - Conservation breeding of Red-Headed vultures and Egyptian vultures.
  - Establishment of vulture-safe zones in each state.
  - Coordinated nation-wide vulture counting.
  - Database on emerging threats to vulture conservation.

Global Efforts

- **SAVE (Saving Asia's Vultures from Extinction):**
  - Consortium of regional and international organizations.
  - Objective: Save three critically important vulture species from extinction.
  - Partners: Bombay Natural History Society, Bird Conservation Nepal, RSPB (UK), National Trust for Nature Conservation (Nepal), International Centre for Birds of Prey (UK), and Zoological Society of London.
- **The Vulture Conservation Foundation:** This is the world's leading organization dedicated solely to the conservation of vultures. They work on a variety of initiatives, including captive breeding, reintroduction programs, research, and education.

Great Indian Bustard

About the Species

- The Great Indian Bustard is one of the rarest birds globally, characterized by its heavy body, horizontal posture, and long bare legs, resembling an ostrich. It is one of the largest flying birds in the world, and India's heaviest flying bird.

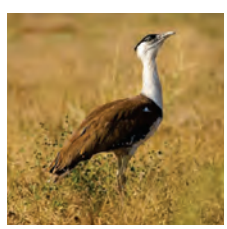


Fig. 6.21: The Great Indian Bustard

- **Habitat:** It inhabits open habitats such as short grasslands, open scrub, and rain-fed agriculture. Breeding occurs in traditionally selected grasslands, with males displaying to attract females. The species avoids irrigated areas.
- GIB is an indicator species for grassland habitats, and its gradual disappearance indicates the deterioration of such environments. Its loss could destabilize the ecosystem of grasslands and impact other critical biodiversity, including blackbucks and wolves that share its habitat.
- **Threats:** Excessive hunting in the past and ongoing habitat loss, coupled with slow life-history traits, have led to a significant decline in their population.
- **Distribution:** Endemic to the Indian subcontinent, GIB is found in central India, western India, and eastern Pakistan. The largest population occurs in the Thar Desert, Rajasthan (Desert National Park spread over Jaisalmer and Barmer districts), with other populations in Kachchh (Gujarat), Solapur and Chandrapur (Maharashtra), Kurnool (Andhra Pradesh), and Bellary (Karnataka).
- **Conservation Initiatives:**
  - GIB is Rajasthan's state bird, and the state government has initiated "Project Godawan" for its conservation at the Desert National Park (DNP) in Jaisalmer.
    - It is part of the Species for The Recovery Programme under the Integrated Development of Wildlife Habitats of the Ministry of Environment and Forests.
- **Conservation Status:**
  - **IUCN Red List:** Critically Endangered
  - **Wildlife Protection Act:** Schedule I
  - **CITES:** Appendix I
  - **Conservation of Migratory Species or Bonn Convention:** Appendix I

Conservation Guidelines: National Guidelines for Recovery of Bustards, 2013

These guidelines advocate a multi-pronged approach, including stringent protection and research-informed management of breeding enclosures, coexistence with compatible land uses, mitigation of unfriendly land uses, community participation, and the establishment of captive populations as insurance against extinction and possible reintroduction. The guidelines aim to benefit not only the Great Indian Bustard but also other endangered wildlife sharing its habitat, such as the spiny-tailed lizard, chinkara, and foxes.

Hangul

The Kashmir stag also called hangul is a subspecies of Central Asian red deer endemic to Kashmir and surrounding areas. It is found in dense riverine forests in the high valleys and mountains of Jammu and Kashmir and northern Himachal Pradesh. In Kashmir, it is found primarily in the Dachigam National Park where it receives protection.

Fig. 6.22: The Kashmir Stag (Hangul)

Conservation Status:

- **IUCN:** Critically Endangered
- **CITES:** Appendix I
- **Threats:** Habitat loss and fragmentation, Poaching for meat and trophies, Predation by feral dogs and other carnivores, Genetic isolation and inbreeding depression, Conflict and disturbance in the region.

Project Hangul (Conservation for Hangul)

- Hangul, also known as The Kashmir stag, is a subspecies of the Central Asian Red Deer.it is found in Dachigam National Park in Kashmir.
- **Conservation Initiative:** Government of Jammu and Kashmir, in collaboration with IUCN and WWF, initiated Project Hangul to address the decreasing population.

Cheetah

- Over 70 years after it went extinct in India. The cheetah has an ancient history in the country, with a Neolithic cave painting of a 'slender spotted feline being hunted' having been found at Chaturbunj Nala in Mandasur, Madhya Pradesh.
- The name 'cheetah' is believed to have originated from Sanskrit word chitrak, which means 'the spotted one'.
- In India, the cheetah population used to be fairly widespread. The animal was found from Jaipur and Lucknow in the north to Mysore in the south, and from Kathiawar in the west to Deogarh in the east.

The cheetah is believed to have disappeared from the Indian landscape in 1947 when Maharaja Ramanuj Pratap Singh Deo of Koriya princely state hunted down and shot the last three recorded Asiatic cheetahs in India. The cheetah was officially declared extinct by the Indian government in 1952.

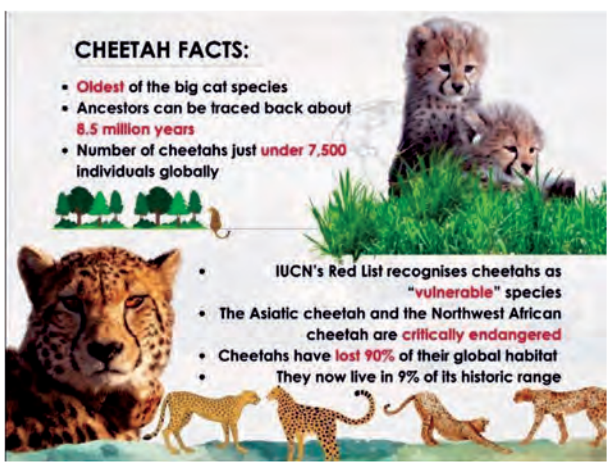

CHEETAH FACTS:
• Oldest of the big cat species
• Ancestors can be traced back about 8.5 million years
• Number of cheetahs just under 7,500 individuals globally
• IUCN's Red List recognises cheetahs as "vulnerable" species
• The Asiatic cheetah and the Northwest African cheetah are critically endangered
• Cheetahs have lost 90% of their global habitat
• They now live in 9% of its historic range

Fig. 6.23: Some Facts about Cheetah

Indian Initiatives for Reintroduction of Cheetah

Project Cheetah: Project Cheetah is the world's first intercontinental large wild carnivore translocation project. The project aimed at the reintroduction of Cheetahs in the country which had become extinct in 1950s in the country.

- It is the world's first inter-continental large wild carnivore translocation project.
- It was launched in September 2022 with the release of eight cheetahs from Namibia, five females and three males.
- It is part of India's efforts to conserve biodiversity and ecosystem services, as well as to restore the cultural and historical significance of cheetahs in India.

Long-Term Vision

- **Phased reintroduction:** The project aims to reintroduce a total of 50 cheetahs over a five-year period, gradually expanding their range to other suitable national parks in India.
- **Ecological benefits:** Cheetah reintroduction is expected to have positive ecological benefits by restoring the balance of the ecosystem and promoting biodiversity.
- **Community engagement:** Local communities are being involved in the project through awareness programs and livelihood initiatives, fostering a sense of ownership and support for cheetah conservation.

Global Initiatives

- **The Cheetah Conservation Fund (CCF):**
  - Established in 1990, the CCF is a non-profit organization dedicated to the long-term survival of the cheetah in the wild.
  - They work across Africa and collaborate with governments, communities, and other organizations to implement various conservation strategies.
  - **Some of their key initiatives include:**
    - Research on cheetah ecology and threats.
    - Anti-poaching patrols and conflict mitigation programs.
    - Community outreach and education programs.
    - Captive breeding and reintroduction programs.
- **The Africa Range-Wide Cheetah Conservation Initiative (CCI):**
  - A coalition of governments, NGOs, and research institutions working together to conserve cheetahs across their range in Africa.
  - Their goal is to improve the conservation status of cheetahs and reverse population declines.
  - They focus on three key areas:
    - **Corridors:** Creating and protecting safe passageways for cheetahs to move between fragmented habitats.
    - **Communities:** Working with local communities to reduce conflict with cheetahs and foster support for conservation.
    - **Capacity:** Building the capacity of local governments and organizations to effectively manage cheetah populations.

Turtle

India is home to a diverse range of turtle species, both freshwater and marine. There are around 25 native turtle species found in India, with several unfortunately facing the threat of extinction.

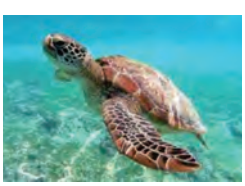


Fig. 6.24: The Green Turtle

- There are five species in Indian waters i.e. Olive Ridley, Green turtle, Loggerhead, Hawksbill, Leatherback.
- Both the Olive Ridley and Leatherback sea turtles have been categorized as 'Vulnerable' on the IUCN Red List.
- The Green Turtle is listed as 'Endangered' and the Loggerhead and Hawksbill turtle is listed as 'Critically Endangered' on the IUCN Red List
  - They are protected in Indian Wildlife Protection Act of 1972, under Schedule I.

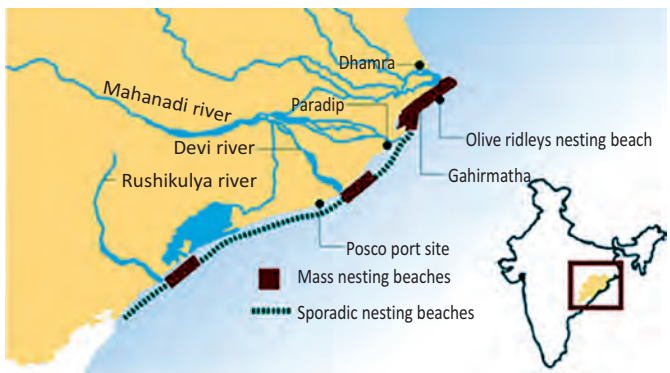


Fig. 6.25: Some Turtle Nesting Beaches

Olive Ridley Turtles in India

- **Habitat:** Olive ridleys are found throughout the Indian mainland, the Andaman and Nicobar Islands, and to a lesser extent, the Lakshadweep Islands.
- **Nesting:** The most important nesting ground for olive ridley turtles in India is Gahirmatha Beach in Odisha, which is part of the Bhitarkanika Wildlife Sanctuary.
  - This mass nesting practice is known as arribadas.

Threats: Unplanned beach development, By-catch mortality, Poaching and consumption, Pollution and habitat degradation.

Turtle Conservation in India

- **The Turtle Wildlife Sanctuary (TWS):** It is a 7 km stretch of the Ganga River that flows through Varanasi, Uttar Pradesh. The sanctuary was established in 1989 as the first freshwater turtle wildlife sanctuary in India. The sanctuary is located between Ramnagar Fort and Malviya Rail/Road Bridge.
- **Sea Turtle Project:** Started in 1999, this project is a joint venture by the Government of India and the UNDP, with the Wildlife Institute of India coordinating various programs, it aims to protect turtle populations by raising awareness, conducting surveys and reviews, GIS studies of nesting areas, TED (Turtle Excluding Devices, used to help turtles escape trawl nets) demonstrations and training for field workers. It works on Olive Ridley turtles on the Eastern coast, mainly in Odisha.
- **The National Marine Turtle Action Plan (2021-2026):** It aims to conserve species, their habitat and reduce negative impacts on survival of marine turtles; improve the understanding of marine turtles and their habitats, through a coordinated mechanism; promote awareness and education on conservation of marine turtles and their habitats; enhance livelihoods of coastal communities through promoting sustainable ecotourism; and increase national, regional and international cooperation on marine turtle conservation.
- **IOSEA Marine Turtle MoU:** The IOSEA Marine Turtle MOU is an intergovernmental agreement that aims to protect, conserve, replenish and recover sea turtles and their habitats in the Indian Ocean and South-East Asian region. It was signed by 33 States and the CMS Secretariat in 2001, and covers six species of marine turtles.
  - The MOU also has an associated Conservation and Management Plan that outlines specific actions and objectives for the conservation of marine turtles and their habitats.
  - The MOU is open for signature indefinitely, and welcomes the participation of other relevant actors and organizations.
- **Operation Save Kurma**

  The operation was conducted by the Wildlife Crime Control Bureau (WCCB) to fight against the increasing illegal trade of live turtles and their parts from the country to destinations abroad.
- **Sahyadri Nisarga Mitra:** This organisation is one of the main turtle conservation initiatives to work on turtle conservation on the Western coast. Passionate about wildlife conservation, the organisation started the Marine Turtle Conservation scheme to protect hatchlings of sea turtles found on the Konkan coast.
  - With the huge success of this project, this organisation now hosts the nation-wide famous 'Turtle Festival' in coastal regions like Velas, to educate populations about the importance of protection of baby turtles.

IGNITE YOUR MIND

Saving the Stars, One by One: Championing Species-Specific Conservation

From the majestic tiger to the elusive snow leopard, numerous initiatives focus on the conservation of specific species. Dive into the success stories and challenges associated with these targeted efforts. If you could choose a species to champion, which would it be and why? What specific actions could you take to become a voice for its survival?

India's commitment to species-specific conservation initiatives reflects a holistic approach that combines science, community involvement, and legal frameworks. While these efforts have made significant strides, ongoing challenges necessitate continued dedication and innovation. By addressing the needs of individual species, India's conservation initiatives contribute not only to the preservation of biodiversity but also to the overall health and resilience of its ecosystems.

OTHER ENVIRONMENTAL ISSUES AND INITIATIVES IN NEWS

- **Green Credit Scheme**
  - The Green Credit Scheme (GCP) is an innovative market-based mechanism launched by the Government of India in October 2023.
  - It aims to incentivize individuals, communities, and businesses to undertake voluntary environmental actions. Participants who engage in activities like tree plantation, water conservation, waste management, and sustainable agriculture can earn "green credits."
  - These credits can be traded on a dedicated platform, allowing participants to benefit financially from their efforts. The GCP is expected to play a significant role in promoting environmental sustainability in India.
- **Nagar Van Scheme:** This is a scheme launched by the Ministry of Environment, Forest and Climate Change in India to develop urban forests in 200 cities across the country in the next five years.
  - The scheme involves people's participation and collaboration between the forest department, municipal bodies, NGOs, corporates and local citizens.
  - The scheme is funded by the Compensatory Afforestation Fund Management and Planning Authority and aims to enhance the tree cover, biodiversity and ecological benefits in urban areas.
- **Forest Fires and Management Strategies:** Forest fires are a major environmental concern, causing widespread damage to ecosystems, property, and human health. Effective forest fire management strategies are crucial for mitigating these risks. Some key strategies include:
  - **Prevention:** This involves measures like controlled burns, fuel reduction, and public awareness campaigns to educate people about responsible behavior in forests.
  - **Detection and Early Warning:** Early detection of fires is essential for prompt response and minimizing damage. This can be achieved through satellite monitoring, watchtowers, and community involvement.
  - **Suppression:** Rapid and effective firefighting techniques are crucial for containing fires and preventing them from spreading. This involves deploying trained personnel and specialized equipment.
  - **Post-fire Rehabilitation:** After a fire, efforts are needed to restore the affected ecosystem. This may involve planting trees, controlling invasive species, and managing erosion.
- **Wildlife and Conservation:** Wildlife conservation is the practice of protecting wild animal and plant species and their habitats. It is essential for maintaining biodiversity, ensuring ecosystem health, and preserving our natural heritage. Conservation efforts involve various strategies, including:
  - **Habitat protection:** Establishing protected areas like national parks and wildlife sanctuaries to provide safe havens for wildlife.
  - **Species management:** Implementing programs to monitor and manage populations of threatened or endangered species.
  - **Anti-poaching measures:** Combating illegal hunting and wildlife trafficking through law enforcement and community engagement.
  - **Public education:** Raising awareness about the importance of wildlife conservation and encouraging responsible behavior towards nature.
- **Indian Star Tortoise:** The Indian star tortoise (Geochelone elegans) is a threatened species of tortoise endemic to India, Pakistan and Sri Lanka. It is characterized by its star-shaped pattern on its carapace and is popular in the illegal pet trade.

Fig.6.26: Indian Star Tortoise

Conservation Status

- IUCN Status: Vulnerable
- Convention on International Trade in Species (CITES): Appendix I
- Wild Life Protection Act 1972: Schedule IV

Habitat loss, fragmentation, and poaching are the main threats to this species. Conservation efforts are underway to protect remaining populations and promote captive breeding programs.

- **Rhino DNA Indexing System (RhODIS):** RhODIS is a forensic tool used to combat rhino poaching. It involves creating a DNA database of rhinos from different populations.
  - When rhino horn is seized, RhODIS can be used to identify the origin of the horn, which can aid in investigations and prosecutions.
  - RhODIS is a valuable tool for wildlife law enforcement agencies in tracking down poachers and disrupting trafficking networks.
- **Global Initiative to End Wildlife Crime:** The Global Initiative to End Wildlife Crime (GIWEC) is a partnership between governments, international organizations, and NGOs established to address the challenges of wildlife crime. GIWEC works on various fronts, including:

- **Enhancing law enforcement cooperation:** Facilitating collaboration between national and international law enforcement agencies to combat wildlife trafficking.
- **Strengthening legal frameworks:** Supporting countries in developing and enforcing effective laws to combat wildlife crime.
- **Reducing demand for illegal wildlife products:** Raising public awareness about the negative impacts of wildlife crime and promoting consumer behavior change.
- **Mobilizing resources:** Securing financial and technical support for countries to combat wildlife crime.

❑ **Global Coalition for Biodiversity:** The Global Coalition for Biodiversity is a multi-stakeholder partnership launched in 2020 to support the implementation of the post-2020 global biodiversity framework. The coalition brings together governments, businesses, NGOs, and indigenous peoples' organizations to work collectively towards achieving the ambitious goals of the framework, which include:

- **Halt biodiversity loss by 2030:** This requires significant efforts to conserve and restore ecosystems, reduce pollution, and promote sustainable resource use.
- **Increase protected areas:** The goal is to effectively conserve at least 30% of the world's lands and oceans by 2030.
- **Reduce resource use and pollution:** This involves transitioning to more sustainable production and consumption patterns to minimize negative impacts on biodiversity.
- **Mobilize resources:** The framework calls for increased financial resources from both public and private sectors to support biodiversity conservation efforts.

❑ **Smart Fencing in Kaziranga:** This is a proposal by the Assam government to install solar fencing in Kaziranga National Park to protect the wildlife from poachers. The park is home to endangered species such as rhinos, tigers, elephants and deer.

- The solar fencing is expected to deter intruders and alert the forest guards in case of any breach.
- The proposal also involves digging the land through the MGNREGA scheme and developing biodiversity parks, butterfly conservatories, water bodies and herbal gardens within the park.

❑ **Illegal Wildlife Trade:** This is the selling or exchange of wild plants and animals that are at risk and protected by law. It involves live plants and animals or products derived from them such as medicine, jewellery, food or clothing.

- It is one of the most lucrative and destructive illegal businesses, often run by organised criminal networks.
- It threatens the survival of many species, the livelihoods of local communities, the public health and the national security of many countries.
- It is regulated by the CITES convention and the Wildlife (Protection) Act in India.

❑ **Cryopreservation:** This technique freezes biological materials like sperm, eggs, and embryos at ultra-low temperatures for long-term storage. It holds potential for preserving genetic material of critically endangered species for future revival attempts.

- Cryopreservation is also known as cryoconservation or cryobanking.

❑ **Humboldt Enigma:** Humboldt enigma is a term used to describe the puzzle of why some mountain regions, especially in the tropics, have exceptionally high biodiversity, contrary to the expected decrease in diversity away from the equator.

- It was named after Alexander von Humboldt, a polymath of the 18th century, who explored the relationship between temperature, altitude, humidity, and species distribution on mountains.
- The eastern Himalayas are an example of Humboldt's enigma, as they boast exceptional diversity despite being outside the tropics.
  - The main drivers of mountain diversity are the history of the earth, geology, geography, and climate.

❑ **Birds in news: Cylon Frogmouth:** Ceylon frogmouth is a small, nocturnal bird found in Sri Lanka and the Western Ghats in India. Related to the nightjars, it is nocturnal and is found in forest habitats. The plumage coloration resembles that of dried leaves and the bird roosts quietly on branches, making it difficult to see. Each has a favourite roost that it uses regularly unless disturbed. It has a distinctive call that is usually heard at dawn and dusk. The sexes differ slightly in plumage.

- **Coppersmith barbet:** The coppersmith barbet, also called crimson-breasted barbet and coppersmith, is an Asian barbet with crimson forehead and throat, known for its metronomic call that sounds similar to a coppersmith striking metal with a hammer. It is a resident bird in the Indian subcontinent and parts of Southeast Asia.
- **Gray-chinned minivet:** The grey-chinned minivet is a species of bird in the family Campephagidae. It is found from the Himalayas to China, Taiwan and Southeast Asia. Its natural habitat is forests about 1,000-2,000 m in elevation. The International Union for Conservation of Nature has assessed it as a least-concern species.
- **White-throated redstart:** The white-throated redstart is a species of bird in the family Muscicapidae. It is found in Nepal, Bhutan, central China and far northern areas of Myanmar and Northeast India. Its natural habitat is temperate forests.

- **Musk deer** (IUCN Status: Endangered) is a small compact deer belonging to the family Cervidae. A solitary shy animal, the musk deer lives in mountainous regions from Siberia to the Himalayas. It is found in states such as Jammu and Kashmir, Assam (Manas National Park), Himachal Pradesh, Uttar Pradesh (Kishanpur Wildlife Sanctuary), Uttarakhand(Askot Wildlife Sanctuary, Gangotri National Park), Sikkim, and Arunachal Pradesh.
- **Kharai Camel:** The Kharai camels are a unique breed of the camel found only in Kutch of Gujarat and feed on mangroves on the island offshore. The Kharai camels can swim up to three kilometers into the sea in search of mangroves, its primary food. People consume their milk, while male calves are sold for economic returns. Given the breed's ability to survive both on land and sea, the Kharai camel is one of the most preferred choices of graziers in the arid coastal region of Kutch. It is one of the larger members of the hornbill family. It is found in the Indian subcontinent (primarily in Western Ghats) and Southeast Asia. It is "Vulnerable" due to high hunting pressure coupled with habitat loss and deforestation. They are seed dispersers and rightly called the 'farmers of the forest'. It is the state bird of Kerala and Arunachal Pradesh. But it is not a state bird of Nagaland although Hornbill Festival is celebrated in Nagaland.
- **Butterflies**

State/UT	State butterfly
Arunachal Pradesh	Kaiser-i-Hind (Teinopalpus imperialis)
Goa	Malabar Tree-Nymph (Idea malabarica)
Jammu and Kashmir	Blue Pansy (Junonia orithya)
Karnataka	Sahyadri Birdwing (Troides minos)
Kerala	Malabar Banded Peacock (Papilio buddha)
Maharashtra	Blue Mormon (Papilio polymnestor)
Sikkim	Blue Duke (Bassarona durga)
Tamil Nadu	Tamil Yeoman (Cirrochroa thais)
Tripura	Common Birdwing (Troides helena)
Uttarakhand	Common Peacock (Papilio bianor)

CHALLENGES ASSOCIATED WITH BIODIVERSITY CONSERVATION IN INDIA

Biodiversity conservation in India is a complex and multifaceted issue that requires coordinated efforts from various stakeholders. Some of the major challenges associated with biodiversity conservation in India are:

- **Habitat loss and fragmentation:** India's rapid population growth, urbanization, industrialization, and agricultural expansion have resulted in the conversion and degradation of natural habitats, leading to the loss of biodiversity and ecosystem services. Habitat fragmentation also reduces the connectivity and resilience of ecosystems, making them more vulnerable to disturbances and invasions.
- **Climate change:** India is highly susceptible to the impacts of climate change, such as rising temperatures, changing precipitation patterns, extreme weather events, sea level rise, and glacial melting. These changes affect the distribution, abundance, phenology, and interactions of species, as well as the functioning and stability of ecosystems. Climate change also exacerbates other threats, such as habitat loss, invasive species, and human-wildlife conflict.
- **Pollution:** India faces serious environmental pollution problems, such as air pollution, water pollution, soil pollution, and noise pollution, due to the lack of adequate regulations, enforcement, and monitoring. Pollution adversely affects the health and survival of biodiversity, as well as the quality and availability of ecosystem services.
- **Invasive species:** India has a high number of invasive alien species, both plants and animals, that have been introduced intentionally or unintentionally through trade, travel, and tourism. Invasive species pose a significant threat to native biodiversity, as they compete with, predate on, hybridize with, or transmit diseases to native species, as well as alter the structure and functioning of ecosystems.
- **Unsustainable exploitation:** India's rich biodiversity is a source of livelihood, food, medicine, and cultural value for millions of people, especially the indigenous and local communities. However, the increasing demand and overexploitation of biological resources, such as timber, fuelwood, non-timber forest products, medicinal plants, wildlife, and fish, have led to the depletion and degradation of biodiversity and ecosystems.

Way Forward

Addressing these challenges demands immediate and decisive efforts from diverse stakeholders, including governmental bodies, civil society organizations, private enterprises, research institutions, and local communities, to preserve and responsibly manage India's biodiversity. Some of the possible actions include:

- **Shifting the Approach:**
  - **Community-based conservation:** Moving away from top-down models, involving local communities in decision-making and benefit-sharing is crucial. This fosters a sense of ownership and responsibility for conservation efforts. Examples include community-managed reserves and joint forest management programs.

- **Landscape-level approach:** Instead of focusing solely on protected areas, considering the broader landscape connectivity is essential. This involves managing corridors between fragmented habitats and integrating conservation into land-use planning.
- **Ecological restoration:** Beyond protection, actively restoring degraded ecosystems is vital for long-term biodiversity conservation. This can involve planting native species, controlling invasive species, and improving habitat quality.

❑ **Addressing Specific Challenges:**

- **Human-wildlife conflict:** Mitigating conflict through measures like early warning systems, habitat corridors, and eco-tourism initiatives can minimize negative impacts on both humans and wildlife.
- **Financing conservation:** Exploring innovative funding mechanisms like green bonds, payments for ecosystem services, and public-private partnerships can help bridge the financial gap for conservation efforts.
- **Knowledge and awareness:** Raising public awareness about the importance of biodiversity and educating communities about sustainable practices are crucial for garnering support and promoting responsible behavior.

❑ **Harnessing Opportunities:**

- **Sustainable development:** Integrating biodiversity conservation into development plans ensures economic growth alongside environmental protection. This can involve promoting eco-friendly practices in agriculture, forestry, and tourism.
- **Technological advancements:** Utilizing tools like remote sensing, drones, and citizen science can enhance monitoring, research, and management of biodiversity resources.

❑ **Policy and regulation:** Strengthening legal frameworks, enforcing existing regulations effectively, and addressing policy gaps can create a supportive environment for conservation initiatives.

IGNITE YOUR MIND

Envisioning a Future Where Nature Thrives:

Close your eyes and imagine a world where humans and nature coexist in harmony. What steps can we take collectively to ensure a sustainable future for our planet's diverse life forms? What legacy do you want to leave behind for future generations? How can your choices today contribute to a world teeming with biodiversity?

CONCLUSION

Biodiversity conservation is a complex and multifaceted endeavor. By employing a diverse range of strategies, addressing underlying threats, and fostering collaborative efforts, we can safeguard our planet's irreplaceable natural heritage for generations to come. The future of biodiversity, and ultimately our own, depends on our collective commitment to reversing the course of the sixth mass extinction and protecting the intricate web of life that sustains us all.

Protected Areas and Conservation Network

7

Biodiversity conservation aims to protect the variety and variability of life on Earth, encompassing all ecosystems, species, and genetic diversity. It recognizes the intrinsic value of biodiversity and its critical role in supporting ecosystem services, human well-being, and ecological stability. Conservation efforts include habitat preservation, species management, sustainable resource use, and policy development to mitigate threats such as habitat loss, pollution, climate change, and overexploitation.

Biodiversity conservation strategies are typically categorized into two main approaches: in situ and ex situ conservation.

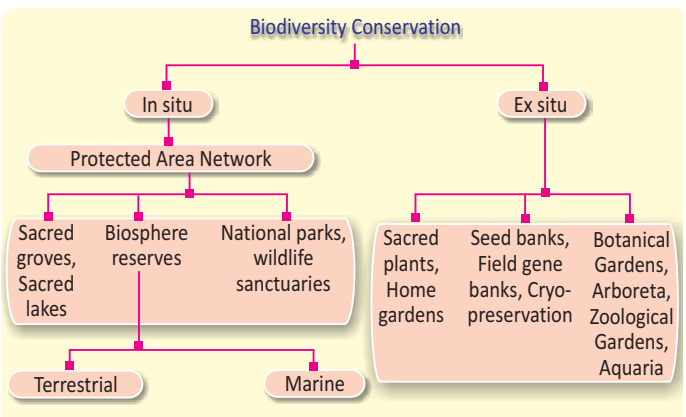


Fig. 7.1: The In-Situ and Ex-Situ Approaches of Conserving Biodiversity in India

PROTECTED AREAS OF INDIA

Protected areas in India are designated regions that are legally protected and managed to conserve biodiversity, preserve natural habitats, and safeguard endangered species. These areas play a crucial role in environmental conservation, ecosystem restoration, and sustainable development efforts across the country.

- Protected areas in India encompass diverse ecosystems, including forests, grasslands, wetlands, coastal areas, and marine habitats, and serve as vital refuges for a wide range of flora and fauna.
- India's network of protected areas includes wildlife sanctuaries, national parks, marine protected areas, conservation reserves, community reserves, biosphere reserves, and other specially designated zones. Each category of protected area serves distinct conservation objectives, ranging from the preservation of specific species to the conservation of entire ecosystems and landscapes.
- The introduction of a **National Policy for Wildlife Conservation in 1970,** followed by the enactment of the Wildlife (Protection) Act in 1972, sparked a notable expansion in the network of protected areas in India. Initially comprising merely 5 national parks and 60 sanctuaries, this network experienced remarkable growth India, as of Nov 2023, has a network of 1014 Protected Areas including 106 National Parks, 573 Wildlife Sanctuaries, 115 Conservation Reserves and 220 Community Reserves covering a total of 1,75,169.42 km2 of geographical area of the country which is approximately 5.32%.
- These protected areas are managed by government authorities, wildlife departments, forest departments, and local communities, with the aim of maintaining ecological integrity, promoting sustainable resource management, and minimizing human-wildlife conflicts.
- They provide opportunities for scientific research, eco-tourism, environmental education, and recreational activities while ensuring the long-term survival of biodiversity and the well-being of local communities.
- India's rich cultural and biological diversity is reflected in its protected areas, which encompass iconic landscapes, endangered species habitats, and culturally significant sites. These areas contribute to the country's global commitments to biodiversity conservation, climate change mitigation, and sustainable development, aligning with international agreements such as the Convention on Biological Diversity and the Sustainable Development Goals.

This chapter delves into the diverse array of protected areas found across India, offering detailed insights into their purposes, distinctions, and relevance in conservation efforts. By examining the various types of protected areas, this chapter aims to enhance understanding of their distinct roles in safeguarding India's natural heritage and fostering sustainable coexistence between humans and the environment.

IGNITE YOUR MIND

Imagine a time machine: You're whisked back 100 years. What would the landscape of a protected area look like then? How would it differ from today's challenges and opportunities?

Reserved and Protected Forest

Under the Indian Forest Act of 1927, Reserved Forests and Protected Forests are two classifications of forest areas with distinct legal statuses and management regimes:

- **Reserved Forest:**
  - Reserved Forests are areas declared as such by the government through a formal notification.
  - These forests are under the exclusive control of the government's forest department, which has the authority to manage and regulate activities within the forest.
  - The primary objective of Reserved Forests is the conservation of forest resources and biodiversity. They are typically subject to stricter regulations to control activities like logging, grazing, hunting, and cultivation.
  - Unauthorized entry and activities in Reserved Forests are prohibited, and permits are required for specific purposes like research, tourism, or commercial exploitation.
- **Protected Forest:**
  - Protected Forests are areas designated by the government for the purpose of protecting specific forest resources or ecosystems.
  - Unlike Reserved Forests, Protected Forests may allow for a wider range of activities, including sustainable resource use, community-based management, and controlled tourism.
  - The level of protection and permitted activities vary depending on the specific objectives and regulations established for each Protected Forest.
  - Protected Forests may include wildlife sanctuaries, conservation reserves, or areas managed under joint forest management schemes.

Both Reserved Forests and Protected Forests play important roles in the conservation and sustainable management of forest resources in India, but they differ in terms of their legal status, management authority, and permitted activities.

NATIONAL PARK

As per the Indian Ministry of Environment & Forests, a national park is any area, whether or not it is part of a sanctuary, that the state government can declare to be a national park due to its ecological, faunal, floral, geomorphological, or zoological significance, which is required to safeguard, propagate, or develop the wildlife in the area. Inside the national park, no human activity is allowed unless approved by the state's chief wildlife warden and subject to the guidelines outlined in Chapter IV of the WPA (1972).

Formation and Regulatory Framework

- **Legislation:** The Wildlife Protection Act of 1972 is the primary legal framework for establishing and managing national parks. Amendments in 1986 and 1991 strengthened conservation measures.
- **Authority:** The Ministry of Environment, Forests and Climate Change (MoEFCC) at the central level and designated forest departments or agencies within state governments have primary responsibility for national park management. So both the centre and states have the power to declare an area as a national park under the Wildlife protection Act.

General Process for Sanctuary and National Park

- **Declaration of the Protected Area by the State Government:**
  - **Initial Notification:** The State Government has the authority to announce its intention to establish a sanctuary or National Park within or outside a reserve forest. This decision is based on the area's significant ecological, faunal, floral, geomorphological, natural, or zoological importance, aimed at safeguarding, nurturing, or enhancing wildlife and its habitat.
  - **Final Notification:** Following the initial notification and upon the expiration of the claims period, the State Government can issue a final notification defining the boundaries of the sanctuary or National Park. This declaration officially designates the area as a sanctuary or National Park, effective from the specified date in the notification.
- **Declaration by the Central Government:**
  - If the Central Government determines that an area possesses significant ecological, faunal, floral, geomorphological, natural, or zoological value for the preservation, propagation, or development of wildlife and its habitat, it holds the authority to declare it as a sanctuary or National Park through an official notification.
- **Boundaries:**
  - The notification must precisely outline the location and extent of the designated area.
  - The state government can change the boundaries of a national park with the approval of the National Board of Wildlife. The state legislature must also pass a resolution to alter the boundaries.
  - If territorial waters are involved, consultations with the Chief Naval Hydrographer of the Central Government are necessary, to ensure the protection of local fishermen's interests.
  - The Amendment Act of 1991 allowed for the inclusion of territorial waters to protect offshore marine flora and fauna.

- **Settlement of Rights:**
  - The State Government is responsible for providing alternative arrangements for fuel, fodder, and other forest produce to affected individuals based on government records.
  - An appointed officer, known as a 'Collector' under the Act, investigates and determines the rights of individuals within the notified sanctuary or National Park.
  - Once an area is notified as a Protected Area, no new rights can be acquired except through succession, testamentary, or intestate means.
- **Claim of Rights:**
  - Claims to rights over the land are reviewed by the Collector, who may admit or reject them either in part or whole.
  - If a claim is admitted, the Collector may exclude the land from the sanctuary's limits, acquire the land or rights, or allow the continuation of existing rights with consultation from the Chief Wildlife Warden.
- **Entry into the Protected Area:**
  - Entry or residence within the sanctuary or National Park is restricted to specific individuals, including public servants on duty, permitted residents, those with property rights, and certain dependents.
  - Entry requires a permit issued by the Chief Wildlife Warden for various purposes such as wildlife study, photography, research, tourism, or lawful business transactions.
- **Grant of Permit for Entry:**
  - The Chief Wildlife Warden is authorized to grant permits for entry or residence in a sanctuary or National Park for specified purposes.
  - The Chief Wildlife Warden holds authority over the management and maintenance of all Protected Areas.
  - The National Board for Wild Life and State Board for Wild Life provide recommendations and advice on the establishment, management, and restriction of activities within these areas, respectively.

Regulations and Prohibitions

- **Restricted Activities:** To safeguard park values, certain activities are prohibited or strictly regulated, including:
  - Hunting, poaching, and wildlife trade.
  - Mining, quarrying, and infrastructure development.
  - Collection of plants, firewood, and non-timber forest products (NTFPs).
  - Grazing, cultivation, and habitation.
  - Pollution, waste disposal, and disturbance of wildlife.
- **Sustainable Activities:** Permissible activities, often managed through zoning, may include:
  - Wildlife viewing and ecotourism
  - Research and education
  - Forest management for ecological restoration
  - Community-based conservation initiatives

Centre-State Collaboration

- **MoEFCC:** Provides policy guidance, financial assistance, technical expertise, and oversees national park management effectiveness.
- **State Governments:** Implement management plans, enforce regulations, allocate resources, and engage local communities.
- **Joint Efforts:** Collaborative planning, monitoring, and capacity building ensure coordinated conservation efforts.

Major National Park

Some Prominent National Parks

- **Keibul Lamjao National Park**
  - Keibul Lamjao National Park is a unique and fascinating place.
  - It is the only floating national park in the world, and an integral part of Loktak Lake, one of the largest freshwater lake in India.
  - The park is home to the endangered brow-antlered deer, also known as Sangai, the state animal of Manipur.
  - The park is made up of phumdis, which are floating masses of vegetation, soil, and organic matter.
  - The park was established in 1977 to protect the Sangai deer or dancing deer (IUCN Status: Endangered) and its habitat.
    - The park is also rich in biodiversity, with many species of birds, mammals, reptiles, fish, and plants.

2. **Kuno National Park**
   - **Established:** 1981 (as Wildlife Sanctuary), 2018 (as National Park).
   - **Location:** Sheopur and Shivpuri districts, Madhya Pradesh.
   - Part of the Khathiar-Gir dry deciduous forests ecoregion.
   - **Famous for:** leopards, sloth bears, spotted deer, and diverse birdlife.
   - **Cheetah Reintroduction Project:** The Cheetah Reintroduction Project is a 13-year-long effort to reintroduce cheetahs to India. The project began on September 17, 2022, when eight cheetahs from Namibia were released in Kuno National Park.
   - Proposal to translocate here some of the lions from their natural habitat in Gujarat.

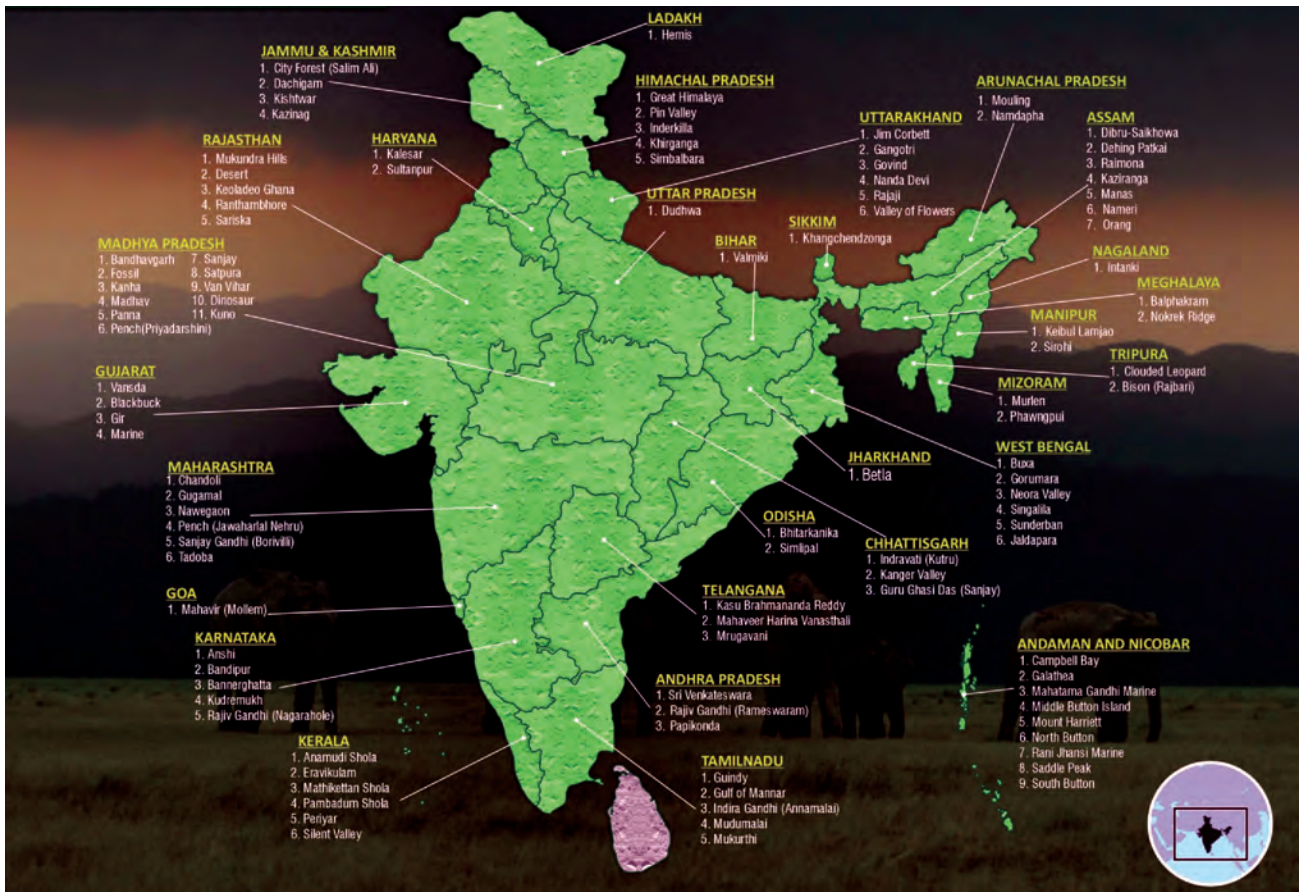


Fig. 7.2: National Parks of India

IGNITE YOUR MIND

Nature's Jigsaw Puzzle: Imagine a fragmented landscape with isolated pockets of protected areas. How can we "rewild" the surrounding areas to create a more connected and resilient conservation network?

3. Hemis National Park

- Established: 1981.
- Location: Eastern Ladakh, India.
- Largest national park in India.
- Second largest contiguous protected area in India.
- Famous for: Snow leopards, Tibetan wolves, Asiatic ibex, Bharal (blue sheep), and diverse birdlife.
- Home to the Hemis Monastery: The park also encompasses the historic Hemis Monastery, a Tibetan Buddhist monastery built in the 17th century.

IGNITE YOUR MIND

The Great Debate: Is it better to have one large, strictly protected area or several smaller, interconnected ones? Why? Explore the strengths and weaknesses of each approach.

4. Jim Corbett National Park

- Located in the Nainital district of Uttarakhand state.
- First national park in India.
- Established in 1936 as Hailey National Park after William Malcolm Hailey, a governor of the United Provinces in which it was then located.
  - Later renamed as Corbett National Park In 1956.
- Launched Project Tiger in 1973.
- **Famous for:** Royal Bengal tigers, Asiatic elephants, diverse birdlife.

5. Ranthambore National Park

- Established initially as Sawai Madhopur Game Sanctuary in 1955, and later declared as a tiger reserve under Project Tiger in 1973.
- Located at the junction of the Aravali and Vindhya hill ranges.
- Home to a huge variety of flora and fauna, including the Royal Bengal tiger, leopard, nilgai, wild boar, sambar, hyena, sloth bear, chital, and many bird species.
- It is one of the best examples of Project Tiger's efforts for conservation in the country, as the number of tigers and their cubs in the park has increased from 66 in 2019 to 81 in 2021.

6. Kaziranga National Park

- Located in the state of Assam, Kaziranga National Park is a UNESCO World Heritage Site and is known for its one-horned rhinoceroses.
- The park is also home to a variety of other animals, including elephants, tigers, leopards, and various bird species.

7. Papikonda National Park

- Papikonda National Park is located near Rajamahendravaram in the Papi Hills of the Alluri Sitharama Raju and Eluru districts of Andhra Pradesh.
  - The park was established as a wildlife sanctuary in 1978 and upgraded to a national park in 2008.
- Some of the animals that can be found in the park are Bengal tiger, Indian leopard, sloth bear, gaur, nilgai, four-horned antelope, rhesus macaque, bonnet macaque, gray langur, black-bellied tern, pale-capped pigeon, yellow-throated bulbul, oriental darter, pallid harrier, Malabar pied hornbill, Alexandrine parakeet, Indian golden gecko, and king cobra.
- It is situated on the left and right banks of the Godavari River and is surrounded by the Papikonda hill range of the Eastern Ghats.
- The park is famous for preserving water buffaloes, which were recorded in the area during the British imperial time.
- It also has a unique dwarf breed of goat known locally as the "kanchu mekha".

Other Important National Parks of India

National Park, Location, Year of Formation	Major Flora and Fauna	Climatic Conditions	Other Important Features
Sundarbans National Park, West Bengal (1984)	Mangrove forests; Bengal Tigers, Estuarine Crocodiles, Gangetic Dolphins	Tropical Monsoon	Largest tidal mangrove forest in the world, UNESCO World Heritage Site
Bandhavgarh National Park, Madhya Pradesh (1968)	Sal forests; Bengal Tigers, Indian Leopards, Indian Gaur	Tropical Monsoon	High density of Royal Bengal Tigers, Ancient Bandhavgarh Fort
Kanha National Park, Madhya Pradesh (1955)	Sal and bamboo forests; Bengal Tigers, Indian Leopards, Indian Sloth Bears, Indian swamp deer (Barasingha)	Tropical Monsoon	Inspiration for Rudyard Kipling's "The Jungle Book"
Gir National Park, Gujarat (1975)	Dry deciduous forests; Asiatic Lions, Indian Leopards, Indian Sloth Bears	Tropical Monsoon	Only natural habitat of Asiatic Lions in the world
Periyar National Park, Kerala (1982)	Tropical evergreen and deciduous forests, Bengal Tigers, Indian Elephants	Tropical Monsoon	Periyar Lake, Wildlife boat cruises, Rich biodiversity
Nagarhole National Park, Karnataka (1988)	Tropical forests, Bengal Tigers, Indian Elephants, Indian Gaurs	Tropical Monsoon	Part of Nilgiri Biosphere Reserve, Significant birdlife, located in Cauvery basin
Pench National Park, Madhya Pradesh (1975)	Teak forests, Bengal Tigers, Indian Leopards, Indian Gaurs	Tropical Monsoon	Inspired Rudyard Kipling's "The Jungle Book"
Tadoba Andhari Tiger Reserve, Maharashtra (1955)	Dry deciduous forests, Bengal Tigers, Indian Leopards, Sloth Bears	Tropical Monsoon	Tiger spotting, Tadoba Lake, Rich biodiversity
Bandipur National Park, Karnataka (1974)	Dry deciduous forests, Indian Elephants, Bengal Tigers, Indian Gaurs	Tropical Monsoon	Part of Nilgiri Biosphere Reserve, Wildlife safaris
Dudhwa National Park, Uttar Pradesh (1977)	Terai forests, Indian Rhinoceros, Bengal Tigers, Indian Elephants	Tropical Monsoon	Protected area for Swamp Deer, Rich avian diversity
Sariska National Park, Rajasthan (1955)	Dry deciduous forests, Bengal Tigers, Indian Leopards, Striped Hyenas	Semi-arid	Historic Sariska Palace, Ancient ruins, Rich biodiversity
Panna National Park, Madhya Pradesh (1981)	Tropical forests, Bengal Tigers, Indian Leopards, Indian Sloth Bears	Tropical Monsoon	Successful tiger reintroduction program, Panna River
Keoladeo National Park, Rajasthan (1982)	Wetlands, Migratory Birds, Sarus Cranes, Pythons, Marsh Crocodiles	Tropical Monsoon	UNESCO World Heritage Site, Important bird sanctuary, Bharatpur
Silent Valley National Park, Kerala (1984)	Tropical rainforests, Lion-tailed Macaques, Elephants, Malabar Giant Squirrels	Tropical Monsoon	Biodiversity hotspot, Unique floral and faunal species

National Park, Location, Year of Formation	Major Flora and Fauna	Climatic Conditions	Other Important Features
Valley of Flowers National Park, Uttarakhand (1982)	Alpine meadows, Himalayan Musk Deer, Snow Leopards, Blue Poppy	Alpine	UNESCO World Heritage Site, Spectacular floral diversity, Trekking destination
Great Himalayan National Park, Himachal Pradesh (1999)	Alpine and temperate forests, Snow Leopards, Himalayan Tahr, Musk Deer	Alpine	UNESCO World Heritage Site, Rich biodiversity, Himalayan landscapes
Gangotri National Park (1989, Uttarakhand)	Chirpine deodar, fir, spruce, oak, rhododendrons snow leopard, musk deer	Subarctic	Gaumukh at Gangotri glacier, the origin of river Ganga, is located inside the park.
Desert National Park (1981, Rajasthan)	Ronj, Khair, Rohira, Dhok, Khejri, Palm trees, Ber, Aak shrub, Sewan grass etc. Great Indian Bustard, Falcons, Eagles, Vultures, Demoiselle Crane, Macqueen's Bustard	subtropical desert climate	Characterized by rolling sand dunes, rocky terrain, and scrubby vegetation. These dunes, known as "dhora," are the park's most iconic feature.
Namdapha National Park (1983, Arunachal Pradesh)	Oak, Magnolia, Pine, Betula, and Rhododendrons Tiger, Leopard, Snow Leopard and Clouded Leopard	Tropical to subtropical, temperate and arctic	Biodiversity hotspot in the Eastern Himalayas. Fourth largest national park in India

Additional Important Information

- **Number of Parks:** As of November 2023, India has 106 existing national parks covering a total area of approximately 44,402.95 sq km, representing 1.35% of the country's geographical area.
- **Biodiversity:** These parks encompass diverse landscapes, from snow-capped Himalayan peaks to tropical rainforests, coastal ecosystems, and arid deserts, harboring a rich tapestry of over 70,000 species of flora and fauna, including many endangered ones.
- **Challenges:** While national parks play a crucial role, they face challenges such as habitat fragmentation, poaching, human-wildlife conflict, and resource constraints. Conservation efforts require ongoing commitment, adaptation, and community engagement.

By understanding the significance, formation, and regulatory framework of national parks in India, we can appreciate their vital role in preserving biodiversity, supporting sustainable livelihoods, and fostering environmental awareness. As responsible citizens, we can contribute to their conservation by advocating for sustainable practices, supporting ecotourism initiatives, and raising awareness about these invaluable natural treasures.

WILDLIFE SANCTUARY

A wildlife sanctuary is a designated area set aside and managed for conservation purposes as well as to offer study and research opportunities. It is important for its flora, fauna, or features of geological or other interest. India's Protected Areas can be established under the Wild Life (Protection) Act, 1972.

- There are 573 existing wildlife sanctuaries in India covering an area of 123,762.56 km2, which is 3.76% of the geographical area of the country (National Wildlife Database Centre, Nov. 2023). Another 218 sanctuaries are proposed in the Protected Area Network Report covering an area of 16,829 km2.

Formation and Regulations

- **Similar to National Parks:** The basic framework for establishment and management is outlined in the Wildlife Protection Act, Both the Central and State Governments can declare an area as a wildlife sanctuary. However, boundaries can be altered by a Resolution of the State Legislature.
- **Flexible Management:** Wildlife sanctuaries have more flexibility in management plans, allowing for variations in activity restrictions based on ecological and social contexts.

Regulations and Prohibitions

- **General Restrictions:** Hunting, poaching, and harmful human activities are prohibited, similar to national parks.
- **Controlled Activities:** Limited activities like grazing, collecting NTFPs, or controlled tourism may be allowed in buffer zones under strict regulations.

Some Prominent Wildlife Sanctuaries

1. **Mudumalai Wildlife Sanctuary**
   - The Mudumalai Wildlife Sanctuary, also known as Mudumalai National Park, is a protected area located in the Nilgiri Hills of Tamil Nadu, India.
   - It covers an area of 321 square kilometers and is part of the Nilgiri Biosphere Reserve.

- The sanctuary is famous for its diverse wildlife, which includes tigers, elephants, gaur, leopards, dholes, sambar deer, spotted deer, barking deer, wild boars, and many more.
- The Mudumalai Wildlife Sanctuary is also home to a variety of birds, including eagles, hawks, owls, hornbills, and woodpeckers.
- The sanctuary is part of the Nilgiri Biosphere Reserve, which is a UNESCO World Heritage Site.

2. Pakhui Wildlife Sanctuary

- The Pakhui Wildlife Sanctuary, also known as the Pakke Tiger Reserve, is a beautiful protected area located in the East Kameng district of Arunachal Pradesh, India.
- Established in 1966, it encompasses an area of 862 square kilometers and is known for its diverse flora and fauna.
- The Pakhui Wildlife Sanctuary is particularly famous for its hornbill population.
- It is home to over 2000 species of plants, including several rare and endangered species like the Hoolock gibbon, the Asian elephant, and the Bengal tiger.

3. Shendurney Wildlife sanctuary

- It is a protected area in the Western Ghats of India, located in the Kollam district of Kerala.
- It is part of the Agasthyamalai Biosphere Reserve.
- It is named after a rare tree species called **Chenkurunji (Gluta travancorica)** that is endemic to this region.

Fig. 7.3: Wildlife Sanctuaries of India

- The sanctuary has a rich diversity of flora and fauna, including endangered and endemic species such as lion-tailed macaque, great eared nightjar, Nilgiri tahr, and Malabar giant squirrel.
- It also has an artificial lake and reservoir of Thenmala Dam.

4. Sathyamangalam Wildlife Sanctuary

- Sathyamangalam Wildlife Sanctuary is a protected area and tiger reserve located in the Erode District of Tamil Nadu, India.
- It is the largest wildlife sanctuary in Tamil Nadu and the third largest in South India.
- It is part of the Nilgiri Biosphere Reserve, located in Cauvery basin and a vital corridor for the movement of elephants, tigers, and other animals between the Western Ghats and the Eastern Ghats.

5. Kishanpur Wildlife Sanctuary

- Kishanpur Wildlife Sanctuary is a part of the Dudhwa Tiger Reserve near Mailani in Uttar Pradesh, India. It was founded in 1972.
- The sanctuary is home to a variety of wildlife, including tigers, leopards, swamp deer, barking deer, Black-necked Stork, and Bengal florican.

Other Important Wildlife Sanctuary of India

Wildlife Sanctuary (Year, Location)	Major Flora and Fauna	Other Important Features	Climatic Conditions
Bhadra Wildlife Sanctuary (1974, Karnataka)	Tropical forests, Indian Elephants, Bengal Tigers, Indian Gaurs.	Tiger reserve, Rich biodiversity.	Tropical
Dandeli Wildlife Sanctuary (1956, Karnataka)	Moist deciduous forests, Malabar Giant Squirrels, Hornbills.	River rafting, Adventure activities.	Tropical to Subtropical.
Manas Wildlife Sanctuary (1928, Assam)	Tropical forests, Indian Elephants, Royal Bengal Tigers, Golden Langurs.	UNESCO World Heritage Site, Tiger reserve, Elephant reserve.	Tropical
Mudumalai Wildlife Sanctuary (1940, Tamil Nadu, Karnataka)	Tropical forests, Indian Elephants, Bengal Tigers, Indian Gaurs	Part of Nilgiri Biosphere Reserve, Wildlife safaris.	Tropical to Subtropical.
Sasan Gir Wildlife Sanctuary (1965, Gujarat)	Dry deciduous forests, Asiatic Lions, Indian Leopards, Sloth Bears.	Only natural habitat of Asiatic Lions in the world.	Arid to Semi-arid.
Tal Chhapar Wildlife Sanctuary (1966, Rajasthan)	Grasslands, Blackbucks, Indian Foxes, Houbara Bustards.	Blackbuck conservation, Birdwatching.	Arid to Semi-arid.
Periyar Wildlife Sanctuary (1950, Kerala)	Tropical evergreen and deciduous forests, Bengal Tigers, Indian Elephants	Periyar Lake, Wildlife boat cruises, Rich biodiversity	Tropical to Subtropical.
Bandhavgarh Wildlife Sanctuary (1968, Madhya Pradesh)	Sal forests, Bengal Tigers, Indian Leopards, Indian Gaurs.	High density of Royal Bengal Tigers, Ancient Bandhavgarh Fort.	Tropical to Subtropical.
Wayanad Wildlife Sanctuary (1973, Kerala)	Gaur, Indian elephant, deer and Bengal tiger	Located in Cauvery basin, part of the Nilgiri Biosphere Reserve	Salubrious climate conditions.
Askot Wildlife Sanctuary (1986, Uttarakhand)	Musk deer, Bengal tiger, Indian leopard, Himalayan jungle cat, civet, barking deer, serow, goral and Himalayan brown bear.	The River Kali forms the international boundary and separates it from Nepal.	Sub-arctic.

National parks and wildlife sanctuaries, with their varying protection levels and management approaches, form a vital network of protected areas in India. Both play crucial roles in safeguarding biodiversity, providing valuable ecosystem services, and fostering environmental awareness. Understanding their distinct characteristics and collaborative management efforts is essential for appreciating their contributions to nature conservation and sustainable development.

Difference between Wildlife Sanctuaries and National Parks

Feature	Wildlife Sanctuary	National Park
Focus	Specific animal species (WLS can be created for a particular species).	Entire ecosystem (flora, fauna, geomorphology, cultural heritage).
Designated by	Central or state government.	Central or state government.
Human activities	Limited, controlled activities allowed.	Strictly prohibited.
Accessibility	Generally open to public with permits.	Entry restricted, may require special permission.
Size	Generally smaller.	Typically larger.
Change in Status	Can be upgraded to a national park.	Cannot be downgraded to a sanctuary.
Examples	Bhadra Wildlife Sanctuary, Pakke (Pakhui) Wildlife Sanctuary, Periyar Wildlife Sanctuary, etc.	Jim Corbett National Park, Kaziranga National Park, Ranthambore National Park, etc..

COMMUNITY RESERVES AND CONSERVATION RESERVES

Community Reserves and Conservation Reserves emerged as a result of amendments to the **Wildlife Protection Act in 2003,** thereby granting legal support to community-led endeavors in wildlife protection. This framework allows for a flexible system that ensures wildlife conservation without disregarding the needs of local communities. These reserves signify two distinct categories of protected areas in India established to uphold the conservation of biodiversity, wildlife habitats, and traditional community lifestyles. Below is an overview of each:

Community Reserves

- Community Reserves are areas owned or managed by local communities, individuals, or organizations, where the community plays a significant role in conservation and sustainable management.
- These reserves are established with the objective of protecting and conserving wildlife, habitats, and traditional cultural practices while promoting community participation and livelihood opportunities.
- The State Government has the authority to designate any community or private land as a Community Reserve, provided that the respective community members or individuals consent to dedicate such areas for the protection of fauna, flora, as well as their traditions, cultures, and practices.
- This declaration aims to enhance the socio-economic conditions of the inhabitants while simultaneously conserving wildlife. The management of the Reserve is entrusted to a Community Reserve Management Committee.
- Upon voluntary commitment from a community or individual to conserve wildlife and its habitat, the State Government can officially declare the area as a community reserve through notification.
- Furthermore, any alteration in the land use pattern within the Community Reserve must adhere to a resolution passed by the Management Committee and subsequently approved by the State Government.
- Community Reserves may include forests, grasslands, wetlands, or other ecosystems with significant biodiversity value and potential for sustainable use.
- The management of Community Reserves is typically guided by a management committee consisting of local stakeholders, representatives of the community, government officials, and experts.
- Activities within Community Reserves may include ecotourism, traditional resource use, habitat restoration, scientific research, and environmental education.

Conservation Reserves

Conservation Reserves are protected areas established by the state government or Union Territory administration for the conservation of landscapes, ecosystems, habitats, and wildlife outside of established national parks and sanctuaries.

- These reserves are designated based on their ecological significance, biodiversity values, or the presence of threatened species, and they aim to provide additional protection to important wildlife habitats and corridors.
- After consulting with local communities, the State Government has the authority to designate any government-owned area as a conservation reserve.
- Tiruppadaimarathur Conservation Reserve, located in Tirunelveli, Tamil Nadu, holds the distinction of being the inaugural conservation reserve established in the country. This initiative emerged from the proactive efforts of the local village community, driven by their desire to safeguard the nesting grounds of birds within their village. Their collective actions led to the formal declaration of Tiruppadaimarathur as a conservation reserve.
- Conservation Reserves may encompass a variety of habitats, including forests, grasslands, wetlands, coastal areas, and marine environments, depending on the conservation needs of the region.

- The management of Conservation Reserves is overseen by the respective state forest department or designated authorities, with input from local communities, conservation organizations, and other stakeholders.
- Conservation Reserves are managed to minimize human disturbances, regulate land use activities, control invasive species, and promote scientific research, monitoring, and community engagement.

Both Community Reserves and Conservation Reserves contribute to the conservation and sustainable management of India's natural heritage, supporting biodiversity conservation, ecosystem services, and local livelihoods. They represent innovative approaches to conservation that integrate traditional knowledge, community participation, and modern conservation strategies to address the complex challenges of biodiversity loss and habitat degradation.

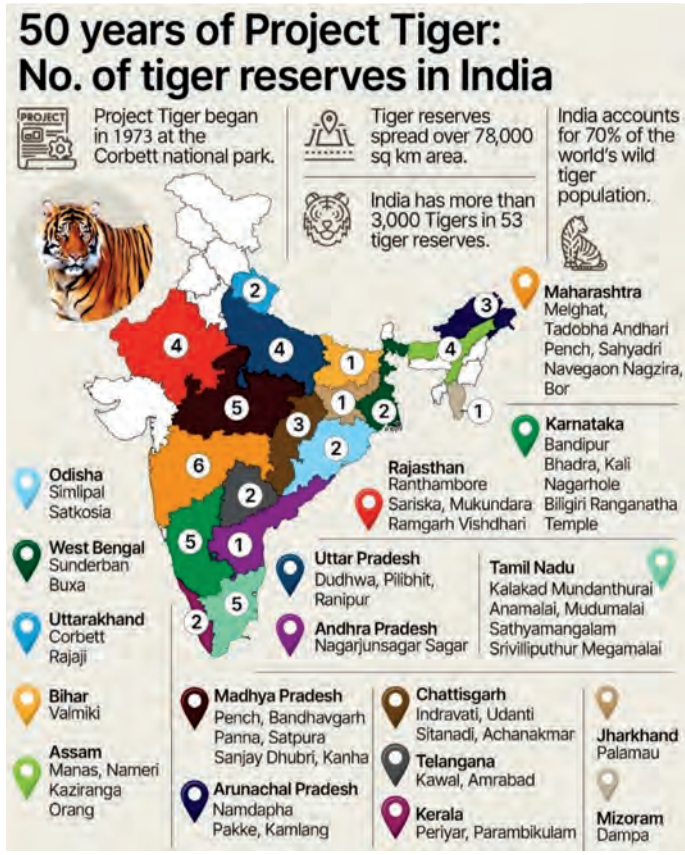
IGNITE YOUR MIND

Conservation on Trial: You're on a jury deciding the fate of a proposed protected area. Local communities argue it restricts their livelihoods, while scientists warn of species extinction. What factors would guide your verdict?

TIGER RESERVES

Tiger reserves are protected areas designated for the conservation of the striped big cats (tigers) and their habitats in India. They are governed under Project Tiger, which is administered by the National Tiger Conservation Authority, Government of India.

- As of 2023, there are 54 tiger reserves in India, with more than 78,000 Square KM area and covers more than 2.30% of geographical area of India. Some of the most famous tiger reserves in India are Corbett, Ranthambore, Bandipur, Kanha, Periyar, and Sundarban.
- As per Wildlife Protection Act (WPA), 1972, the State Government, based on recommendations from the National Tiger Conservation Authority (NTCA), notifies an area as a tiger reserve.
- A tiger reserve comprises a core zone and a buffer zone:
  - **Core Zone:** Critical tiger habitat areas kept inviolate for tiger conservation, notified by the State Government in consultation with an Expert Committee.
  - **Buffer Zone:** Peripheral area surrounding the core zone, aiming to promote co-existence between wildlife and human activities while respecting local livelihoods and rights.
- Any alteration in the boundaries of a tiger reserve requires NTCA recommendation and approval from the National Board for Wildlife.
- De-notification of a tiger reserve by a State Government is only possible with NTCA and National Board for Wildlife approval, and in the public interest.



***Recently, Dholpur-Karauli became India's 54th Tiger Reserve.

Fig. 7.4: Tiger Reserves of India

Important Tiger Reserves of India

Tiger Reserve	Notable Features
Jim Corbett Tiger Reserve, Uttarakhand	Oldest national park in India; significant population of Bengal Tigers; diverse wildlife and scenic beauty.
Nagarjunsagar-Srisailam Tiger Reserve, Andhra Pradesh & Telangana	Largest tiger reserve in India; critical habitat for Bengal Tigers, Indian Leopards, and various other wildlife species; diverse ecosystems.
Pilibhit Tiger Reserve, Uttar Pradesh	One of the smallest tiger reserves in India; significant population of Bengal Tigers, swamp deer, and over 200 bird species; diverse flora and fauna.
Ranthambore Tiger Reserve, Rajasthan	Historic Ranthambore Fort; habitat for tigers, leopards, sloth bears, and various bird species; diverse vegetation and landscapes.
Kaziranga Tiger Reserve, Assam	UNESCO World Heritage Site; tall grasslands; significant population of Indian Rhinoceros, Bengal Tigers, Asian Elephants, and various bird species; diverse ecosystems.

Tiger Reserve	Notable Features
Bandhavgarh Tiger Reserve, Madhya Pradesh	High density of Royal Bengal Tigers; ancient Bandhavgarh Fort; rich biodiversity including leopards, sloth bears, and over 250 bird species; scenic beauty of Sal forests.
Sunderbans Tiger Reserve, West Bengal	Largest estuarine mangrove forest; critical habitat for Bengal Tigers, estuarine crocodiles, and various bird species; unique ecosystem adapted to tidal influences.
Tadoba-Andhari Tiger Reserve, Maharashtra	Dense forests; significant population of Bengal Tigers, Indian Leopards, sloth bears, and gaur; diverse flora and fauna; picturesque landscapes.
Kanha Tiger Reserve, Madhya Pradesh	Inspiration for "The Jungle Book"; diverse wildlife including Bengal Tigers, Indian Leopards, and Barasingha deer; lush forests and grasslands.
Pench Tiger Reserve, Madhya Pradesh & Maharashtra	Scenic beauty; teak forests; habitat for Bengal Tigers, leopards, Indian wild dogs, and over 285 bird species; diverse flora and fauna.

The National Tiger Conservation Authority (NTCA)

- The National Tiger Conservation Authority (NTCA) is a legal entity established under the Ministry of Environment, Forests, and Climate Change, in accordance with the Wildlife (Protection) Act of 1972, as amended in 2006. Its primary objective is to enhance tiger conservation efforts by exercising the powers and duties delegated to it by the aforementioned legislation.
- NTCA diligently executes its responsibilities outlined in the Wildlife (Protection) Act of 1972 to bolster tiger preservation across the nation. This is achieved through continuous monitoring and assessment of the tiger population status, ongoing conservation projects, and insights from specialized committees. NTCA also provides guidance and normative directives to ensure effective tiger conservation practices are upheld.
- The aims of the NTCA encompass several key objectives:
  - Granting statutory authority to Project Tiger, thereby rendering compliance with its directives legally binding.
  - Enhancing the accountability of both the central and state governments in the management of Tiger Reserves, facilitating the establishment of Memoranda of Understanding (MoUs) with states within the federal structure.
  - Instituting a system of oversight by Parliament.
  - Addressing the livelihood concerns of local communities residing in the vicinity of Tiger Reserves.
- **The powers and functions of the National Tiger Conservation Authority, as delineated in Section 38-O (1) and (2) of the Wildlife (Protection) Act of 1972, as amended in 2006, include:**
  - Approval of tiger conservation plans formulated by State Governments (Section 38 O (1) (a)).
  - Evaluation and assessment of various ecological aspects to prevent unsustainable land use practices such as mining and industrial activities within tiger reserves.
  - Establishment of normative standards for tourism activities and periodic issuance of guidelines for Project Tiger to ensure conservation efforts in both buffer and core areas of tiger reserves.
  - Management focus on addressing human-wildlife conflicts and promoting coexistence in forest areas beyond National Parks, sanctuaries, or tiger reserves.
  - Provision of information on protection measures, conservation plans, population estimates of tigers and prey species, habitat status, disease surveillance, mortality surveys, patrolling, and other pertinent management aspects.
  - Approval and coordination of research and monitoring efforts pertaining to tigers, their prey, habitat, and associated ecological and socio-economic parameters.
  - Ensuring that tiger reserves and connecting areas between protected areas are not diverted for unsustainable purposes, except in cases of public interest and with appropriate approvals.
  - Facilitation and support of biodiversity conservation initiatives within tiger reserves and adjoining areas through eco-development and community participation in line with approved management plans and relevant laws.
  - Provision of critical support, including scientific, technological, and legal assistance, to enhance the implementation of tiger conservation plans.

The Tiger Conservation Authority may, in the exercise of its powers and performance of its functions under this Chapter, issue directions in writing to any person, officer or authority for the protection of tiger or tiger reserves and such person, officer or authority shall be bound to comply with the directions.

IGNITE YOUR MIND

Animal Espionage: You're tasked with developing a high-tech animal spy gadget to monitor protected areas discreetly. What features would it have, and what challenges might you face in deploying it?

Critical Tiger Habitat

Critical tiger habitat refers to the core areas within tiger reserves that are deemed essential for the conservation and survival of tiger populations.

- The **state government,** in consultation with an expert committee established for this purpose, is responsible for officially notifying these Critical Tiger Habitats (CTH).
- These areas are designated under the **Wild Life Protection Act (WLPA) of 1972** and are identified based on scientific and objective criteria, taking into account factors such as habitat suitability, prey availability, and tiger movement patterns.
- Critical tiger habitats are designated as inviolate zones where human activities are restricted to minimize disturbances to tiger populations and their habitats. Protecting these areas is crucial for ensuring the long-term survival of tigers and maintaining healthy ecosystems.

CRITICAL WILDLIFE HABITAT (CWH)

The preservation of biodiversity and the protection of wildlife habitats have become increasingly critical in the face of growing environmental challenges. Recognizing the importance of safeguarding these habitats, the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, introduced the concept of Critical Wildlife Habitats (CWH).

- **Defining Critical Wildlife Habitats**
  - According to the Act, Critical Wildlife Habitats are "areas of national parks and sanctuaries where it has been specifically and clearly established, case by case, on the basis of scientific and objective criteria, that such areas are required to be kept as inviolate for the purposes of wildlife conservation." This definition underscores the imperative to maintain these areas free from human presence to ensure the survival and well-being of wildlife species.
- **Designation Process**
  - The responsibility for designating CWH lies with the Ministry of Environment and Forests. The State Governments initiate the process by submitting applications on a case-by-case basis to the Ministry, which serves as the nodal agency under the Act. It's important to note that only the Central Government has the authority to declare CWHs, emphasizing the centralized approach to their designation.
- **Balancing Conservation and Tribal Rights**
  - A key consideration in establishing CWHs is addressing the rights of forest dwellers. Before notification, the rights of tribals and forest dwellers must be settled, and scientific evidence must demonstrate the adverse impact of human presence on wildlife. Additionally, the consent of the affected Gram Sabha, the local village council, is essential.
  - Their free and informed consent is necessary before any relocation of forest dwellers is undertaken, highlighting the importance of community involvement in conservation efforts.
- **Challenges and Conservation Efforts**
  - CWHs face various threats, including habitat loss, fragmentation, and climate change. Conservation efforts involve minimizing human disturbances, implementing habitat restoration measures, and enforcing regulations to prevent unauthorized activities such as deforestation and poaching.
  - Sustainable land use practices and community engagement are crucial for effectively conserving these habitats and the species they support.

Critical Wildlife Habitats play a pivotal role in biodiversity conservation efforts, serving as sanctuaries for endangered species and preserving their habitats for future generations. By striking a balance between conservation imperatives and tribal rights, we can ensure the long-term survival of wildlife and promote harmonious coexistence between humans and nature. Through collaborative efforts and sound management practices, we can secure the future of our natural heritage for generations to come.

BIOSPHERE RESERVE

- A biosphere reserve is typically a distinct area comprising terrestrial, marine, or coastal ecosystems, subject to specific management protocols aimed at preserving habitats and biological diversity while emphasizing the harmonious coexistence of human activities with the environment.
- These reserves, designated by UNESCO, serve as educational hubs for sustainable development, facilitating the study of the intricate interplay between societal dynamics and ecosystems. This includes exploration of both challenges and collaborative efforts in biodiversity conservation and ecosystem management.
- According to UNESCO Biosphere reserves are 'learning places for sustainable development'. They are sites for testing interdisciplinary approaches to understanding and managing changes and interactions between social and ecological systems, including conflict prevention and management of biodiversity. They are places that provide local solutions to global challenges. Biosphere reserves include terrestrial, marine and coastal ecosystems. Each site promotes solutions reconciling the conservation of biodiversity with its sustainable use.
- Biosphere reserves are nominated by national governments and remain under the sovereign jurisdiction of the states where they are located.
- Biosphere Reserves are designated under the intergovernmental Man and Biosphere (MAB) Programme by the Director-General of UNESCO following

the decisions of the MAB International Coordinating Council (MAB-ICC). Their status is internationally recognized. Member States can submit sites through the designation process.

- The Man and Biosphere Programme (MAB), launched by UNESCO in 1971, aims to improve the relationship between human societies and their environments. It combines various disciplines such as natural and social sciences, economics, and education to promote human well-being, equitable distribution of benefits, and conservation of ecosystems. MAB encourages innovative and sustainable economic development approaches while fostering harmony between people and their surroundings.

- The World Network of Biosphere Reserves (WNBR), established by UNESCO in 1971, promotes sustainable development by conserving biological and cultural diversity. Biosphere reserves serve as models for sustainable development, integrating biodiversity conservation with the responsible use of natural resources and socio-economic growth.

The National Biosphere Reserve Program

The National Biosphere Reserve Program of 1986 was initiated in India to establish a network of protected areas known as Biosphere Reserves (BRs). Here's a brief overview:

- **Objective:**
  - The primary objective of the program was to conserve biological diversity and promote sustainable development in designated areas by integrating conservation with human activities.
  - It should be mentioned that BRs serve to reinforce the current protected areas rather than to replace or offer an alternative.
  - The Core Group of Experts has identified the following goals for the Biosphere Reserve programme.
  - To protect the genetic diversity of species that is essential to their ongoing evolution. To provide areas for multidisciplinary research and monitoring.
  - To provide facilities for education and training.
  - To ensure sustainable use of natural resources through the most appropriate technology for the improvement of the local population's economic well-being.

- **Designation of Biosphere Reserves:** Under this program, certain areas were designated as Biosphere Reserves based on their ecological significance, unique biodiversity, and potential for sustainable development.Biosphere reserves are nominated by national governments and remain under the sovereign jurisdiction of the states where they are located.

- **Core Areas and Buffer Zones:** Each Biosphere Reserve typically consists of three zones: a core area, a buffer zone, and a transition area. The core area is strictly protected to conserve biodiversity, while the buffer zone allows for sustainable resource use and human activities. The transition area facilitates cooperation between conservation and development.

- Conservation and Research: Biosphere Reserves serve as platforms for scientific research, monitoring of ecosystems, and conservation initiatives. They also promote education and awareness about biodiversity and sustainable development.

- Recognition by UNESCO: Biosphere Reserves designated under this program may be recognized by UNESCO's Man and the Biosphere (MAB) Programme, providing them with international recognition and support.

Overall, the National Biosphere Reserve Program of 1986 aimed to conserve natural resources, promote sustainable development, and foster harmonious relationships between humans and the environment within designated areas of ecological importance.

What Factors are Considered When Designating a Biosphere Reserve?

- **Primary Criteria:**
  - The site must encompass a core area that is effectively protected and minimally disturbed, showcasing significant value for nature conservation. Additionally, it should include additional land and water bodies suitable for research and the demonstration of sustainable methods of management.

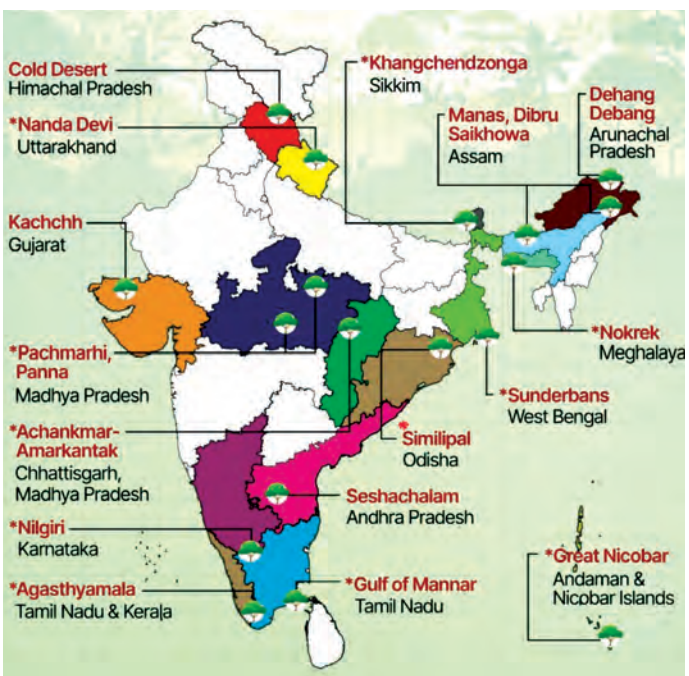


Fig. 7.5: Biosphere Reserve of India

- The core area should represent a biogeographical unit and be sufficiently large to support viable populations representing all trophic levels within the ecosystem.

❑ **Secondary Criteria:**

- Presence of rare and endangered species within the area.
- Existence of diverse soil and micro-climatic conditions, along with indigenous varieties of biota.
- Potential for the preservation of traditional tribal or rural lifestyles that involve harmonious utilization of the environment.

Functions of Biosphere Reserves

The functions of biosphere reserves revolve around conservation, sustainable development, research, education, and fostering community involvement. Here's a brief overview of these functions:

❑ **Conservation:**

- Protecting landscapes, ecosystems, species, and genetic diversity.
- Preserving cultural and traditional resource use practices.
- Ensuring the sustainability of natural resources and ecosystems.
- Monitoring and mitigating the impacts of human activities on biodiversity.

❑ **Sustainable Development:**

- Promoting economic activities that are culturally, socially, and ecologically sustainable.
- Supporting livelihoods that depend on natural resources, while ensuring their long-term viability.
- Developing strategies for sustainable land and resource management.

❑ **Research:**

- Conducting scientific research to understand ecosystem dynamics, biodiversity, and the effects of human activities.
- Monitoring environmental changes and their impacts on ecosystems and communities.
- Investigating innovative approaches to conservation and sustainable development.

❑ **Education and Awareness:**

- Providing environmental education and awareness programs for local communities, schools, and visitors.
- Fostering knowledge exchange and capacity building among stakeholders.
- Raising awareness about the importance of biodiversity conservation and sustainable living practices.

❑ **Community Involvement:**

- Engaging local communities in the management and decision-making processes of biosphere reserves.
- Empowering indigenous peoples and traditional resource users to participate in conservation and sustainable development initiatives.
- Encouraging collaborative partnerships between government agencies, NGOs, researchers, and local communities.

Overall, biosphere reserves serve as living laboratories for testing and implementing innovative approaches to balancing conservation and development goals. They aim to protect natural ecosystems while supporting the well-being of both human communities and the environment.

Structure

The structure of a biosphere reserve typically consists of three main zones or areas, each serving specific purposes and management objectives. These zones are designed to balance conservation with sustainable development and human activities:

❑ **Core Area:**

- The core area is the central, most strictly protected zone within the biosphere reserve. It encompasses pristine habitats and ecosystems that are minimally disturbed by human activities.
- The core area serves as a reference area for scientific research, providing essential insights into natural processes and biodiversity conservation. Human activities in the core area are limited to non-destructive research and monitoring activities.
- This zone aims to maintain the ecological integrity of the reserve and protect critical habitats and species.

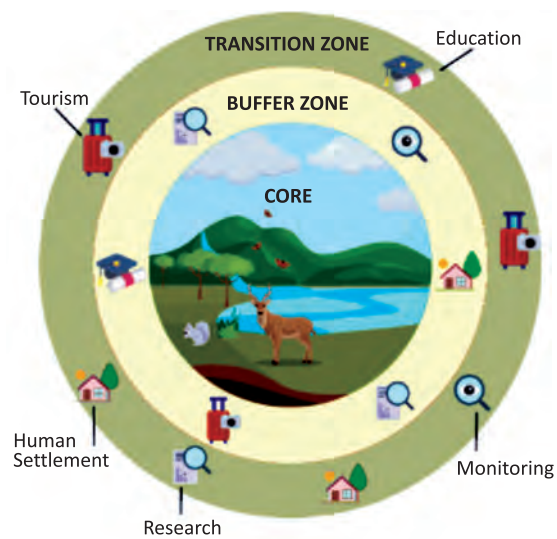


Fig. 7.6: Zones of Biosphere Reserves

❑ **Buffer Zone:**

- Transition area between the core zone and the surrounding human-dominated landscapes.
- The buffer zone allows for sustainable land use practices, resource management, and compatible economic activities such as agriculture, forestry, and tourism. While certain human activities are permitted in this zone, they must be conducted in a manner that minimizes negative impacts on the core area's ecological values.
- The buffer zone facilitates the engagement of local communities in conservation efforts and promotes the sustainable use of natural resources.

- **Transition Area or Outer Zone:**
  - The outermost zone of the biosphere reserve is known as the transition area or outer zone. This zone encompasses the broader region surrounding the core and buffer zones and includes human settlements, agricultural lands, urban areas, and industrial zones.
  - While the transition area may experience more intensive human activities compared to the core and buffer zones, efforts are made to promote sustainable development practices, biodiversity conservation, and environmental education.
  - Collaborative management approaches involving local communities, government agencies, NGOs, and other stakeholders are often implemented to address conservation challenges and promote socio-economic development that is compatible with biodiversity conservation goals.

How Biosphere Reserves are Different from Protected Areas?

Biosphere Reserves (BRs) stand out from traditional protected areas due to their unique emphasis on several key aspects:

- **Conservation of Overall Biodiversity:** BRs prioritize the conservation of entire ecosystems and landscapes rather than focusing solely on flagship species. This approach allows natural processes to continue without disruption.
- **Comprehensive Components:** BRs encompass various components such as landscapes, habitats, species, and land races, providing a holistic approach to conservation.
- **Balancing Development and Conservation:** BRs strive to resolve conflicts between developmental activities and conservation goals, aiming for sustainable and harmonious coexistence.
- **Stakeholder Engagement:** They emphasize broad-based stakeholder participation, particularly involving local communities. This approach contrasts with schemes focusing solely on wildlife sanctuaries and national parks.
- **Sustainable Development:** BRs promote environmentally friendly development practices while fostering coordination among different organizations and agencies involved in development efforts.
- **Research and Monitoring:** BRs facilitate research and monitoring to better understand ecological systems and their responses to human interventions, enabling informed management decisions.
- Internationally, BRs are recognized within UNESCO's Man and Biosphere (MAB) program, following the consent of the participating country, further enhancing their global significance in biodiversity conservation and sustainable development efforts.

Biosphere Reserves of India

S.No.	Biosphere Reserve, Location (State), Year of Formation	Key Fauna	Area (in sq. km)	Other Important Aspects
1	*Nilgiri Biosphere Reserve, Tamil Nadu, Kerala, Karnataka, 1986	Lion-Tailed Macaque (EN), Nilgiri Tahr (EN), Malabar Giant Squirrel (LC), Nilgiri Langur (VU).	5520	Wayanad, Nagarhole, Bandipur and Mudumalai, Nilambur, Silent Valley national parks form part of Nilgiri BR. Included in MAB in 2000
2	*Nanda Devi Biosphere Reserve, Uttarakhand, 1988	Snow Leopard (VU), Musk Deer (EN), Bharal Or Blue Sheep (LC).	5860.69	Parts of Chamoli District, Pithoragarh District & Bageshwar District Included in MAB in 2004.
3	*Nokrek, Meghalaya, 1988	Red Panda (EN), Hoolock Gibbons (EN), Red Giant Flying Squirrel (LC).	820.00	In West Garo Hills Included in MAB in 2009.
4	*Gulf of Mannar, Tamil Nadu, 1989	Dugong (VU), Olive Ridley turtles (VU).	10500	Indian part of Gulf of Mannar extending from Rameswaram island in the north to Kanyakumari in the south of Tamil Nadu and Sri Lanka Included in MAB in 2001.
5	*Sundarbans, West Bengal, 1989	Royal Bengal Tiger (EN).	9630	Part of delta of Ganges and Brahmaputra river system Included in MAB in 2001.

6	Manas, Assam, 1989	Assam Roofed Turtle (CR), Hispid Hare (EN), Golden Langur (EN), Pygmy Hog (EN), Wild Water Buffalo (EN), Bengal florican (CR).	2837	Part of Kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamrup and Darrang Districts.
7	*Great Nicobar, Andaman and Nicobar Islands, 1989	Dugong (VU), Saltwater Crocodile (LC).	885	Southernmost of the Andaman and Nicobar Islands Included in MAB in 2013.
8	*Simlipal, Odisha, 1994	Royal Bengal Tiger (EN), Wild Elephants (EN), Gaurs (VU – Indian Bison), Chausingha (VU).	4374	Part of Mayurbhanj district. Included in MAB in 2009.
9	Dihang-Dibang, Arunachal Pradesh, 1998	Takin (VU), Red Panda (EN).	5112	Part of Siang and Dibang Valley.
10	Dibru-Saikhowa, Assam, 1997	Bengal Tiger (EN), Clouded Leopard (VU), Gangetic Dolphin (EN).	765	Part of Dibrugarh and Tinsukia districts.
11	*Pachmarhi, Madhya Pradesh, 1999	Tiger, Gaur, Indian Giant Flying Squirrels (LC).	4926	Parts of Betul District, Hoshangabad District and Chhindwara District Included in MAB in 2009.
12	*Khangchendzonga, Sikkim, 2000	Red Panda (EN), Snow Leopard (VU), Musk Deer (EN), Great Tibetan Sheep (Argali – NT).	2620	Parts of Kangchenjunga Included in MAB in 2018.
13	*Agasthyamalai, Kerala, Tamil Nadu, 2001	Nilgiri Tahr (EN), Asian Elephant.	3500.08	Neyyar, Peppara and Shenduruny Wildlife Sanctuary and their adjoining areas Included in MAB in 2016.
14	*Achanakmar-Amarkantak, Madhya Pradesh, Chhattisgarh, 2005	Four-Horned Antelope (Chausingha (EN)), Indian Wild Dog (VU), sarus crane, white-rumped vulture, sacred grove bush frog.	3835	Part of Annupur, Dindori and Bilaspur districts Included in MAB in 2012.
15	Great Rann of Kutch (Kachchh), Gujarat, 2008	Great Indian Bustard (CR), Indian Wild Ass (NT).	12454	Part of Kutch, Morbi, Surendranagar and Patan districts; the largest biosphere reserve in India.
16	Cold Desert, Himachal Pradesh, 2009	Snow Leopard (VU), Himalayan Ibex (also referred to as Siberian Ibex – NT).	7770	Pin Valley National Park and surroundings; Chandratal and Sarchu & Kibber Wildlife Sanctuary.
17	Seshachalam Hills, Andhra Pradesh, 2010	Red Sanders (EN), Golden Gecko (LC – Endemic To Tirumala Hills).	4755.997	Seshachalam Hill Ranges covering parts of Chittoor and Kadapa districts.
18	*Panna, Madhya Pradesh, 2011	Tiger (EN), Chital (LC), Chinkara (LC), Sambar (VU).	2998.98	Part of Panna and Chhattarpur districts. Included in MAB in 2020.

* Part of the UNESCO List of Man and Biosphere Reserves Programme.

BIODIVERSITY HERITAGE SITES

Biodiversity Heritage Sites (BHS) in India are areas of ecological significance designated for the conservation of unique biodiversity and ecosystems. Under the Biological Diversity Act of 2002, the State Government, in collaboration with local authorities, has the authority to designate areas of biological significance as Biodiversity Heritage Sites (BHS). Typically, the utilization of resources by the community within designated BHS is not anticipated to be constrained in any manner. Some key aspects of Biodiversity Heritage Sites in India are as follow:

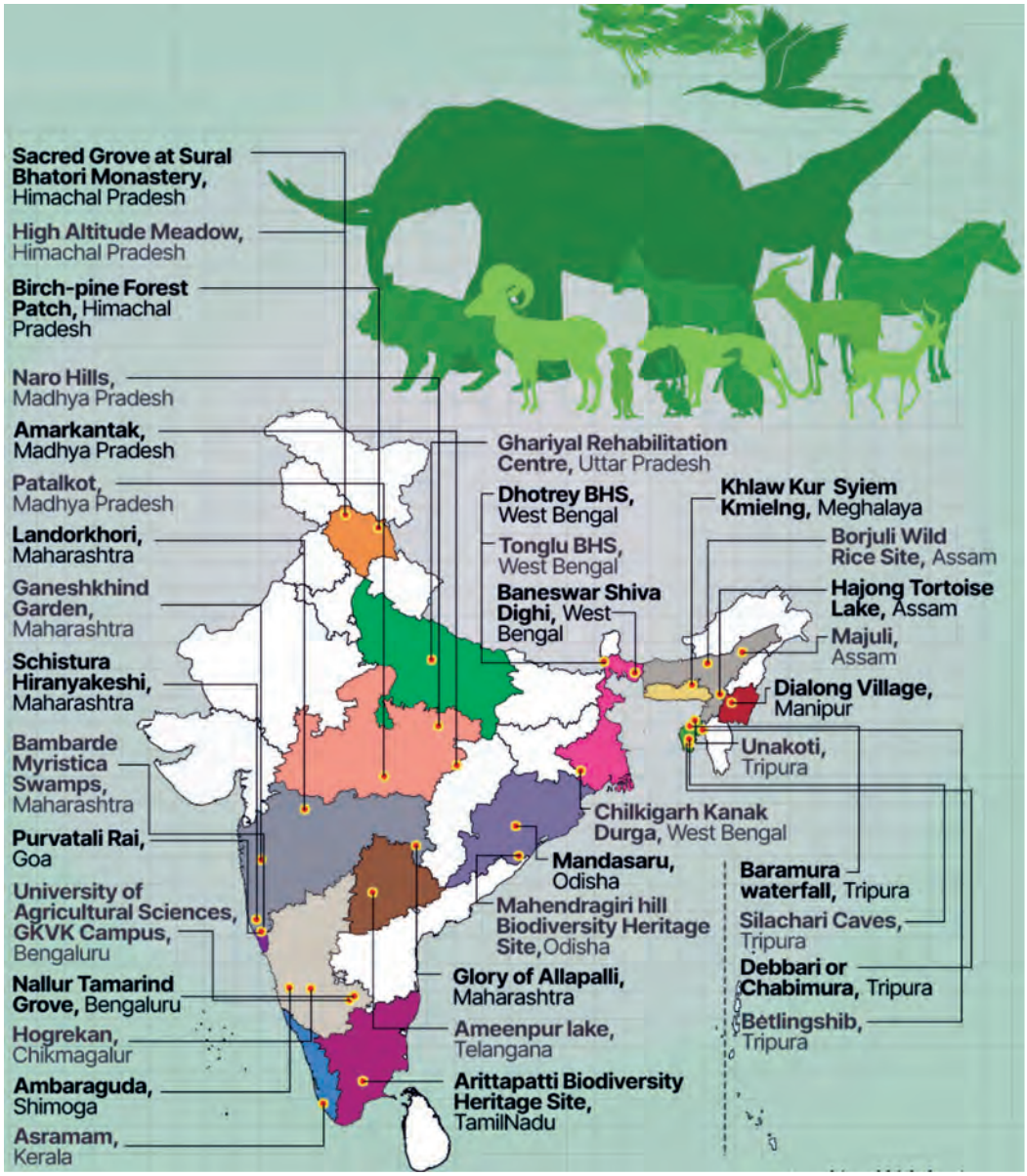


Fig. 7.7: Biodiversity Heritage Sites in India

Purpose and Objectives

- Biodiversity Heritage Sites are identified and designated under the Biological Diversity Act, 2002, with the aim of conserving biodiversity hotspots, rare and endangered species, and ecologically fragile ecosystems.
- The primary objectives of BHS include the conservation of genetic diversity, protection of rare and threatened species, maintenance of ecological balance, and promotion of scientific research and education.

Criteria for Designation

- BHS are selected based on scientific criteria, including the presence of endemic species, unique ecosystems, representative habitats, and traditional knowledge systems associated with biodiversity conservation.
- Sites may include forests, wetlands, grasslands, coastal areas, and other natural landscapes of ecological importance.

Designation Process

- The process of designating Biodiversity Heritage Sites involves scientific assessments, stakeholder consultations, and approval by the State Biodiversity Boards and the National Biodiversity Authority.
- Under the Biological Diversity Act of 2002, the State Government, in collaboration with local authorities, has the authority to designate areas of biological significance as Biodiversity Heritage Sites (BHS).
- Local communities, indigenous peoples, conservation organizations, and experts play a crucial role in identifying and nominating potential BHS.

Management and Conservation

- BHS are managed by the respective State Biodiversity Boards, with support from local authorities, conservation NGOs, and other stakeholders.

- Management plans for BHS focus on habitat restoration, invasive species control, biodiversity monitoring, eco-tourism development, and community-based conservation initiatives.

Recognition and Protection

- Biodiversity Heritage Sites receive legal recognition and protection under the Biological Diversity Act, 2002, and relevant state biodiversity regulations.
- Activities such as mining, quarrying, commercial logging, and other harmful practices are restricted or prohibited within BHS to ensure the conservation of biodiversity values.

Biodiversity Heritage Sites play a crucial role in conserving India's rich biological diversity, preserving rare and endemic species, and maintaining ecosystem services essential for human well-being. Their designation and effective management contribute to sustainable development, ecological resilience, and the promotion of harmony between people and nature.

BIRD SANCTUARIES

- A bird sanctuary is a protected area designated specifically for the conservation and preservation of avian species and their habitats. These sanctuaries serve as safe havens where birds can nest, breed, and feed without disturbance, helping to maintain and enhance bird populations.
- Bird sanctuaries are typically declared by government authorities at the national or state level. The process usually involves identifying areas with significant bird populations or critical habitats for migratory birds. Environmental assessments and consultations with experts may also be conducted to determine the suitability of an area for sanctuary status.
- Once identified, the government officially designates the area as a bird sanctuary through legal mechanisms such as legislation or government notifications.
- The authority responsible for the management and maintenance of bird sanctuaries varies depending on the jurisdiction. In India, bird sanctuaries are often managed by the respective state forest departments or wildlife conservation agencies. These authorities are tasked with enforcing regulations, conducting research and monitoring activities, habitat restoration, and promoting conservation awareness among local communities and visitors. Additionally, NGOs and local community groups may also play a role in the management of bird sanctuaries through collaborative conservation initiatives and ecotourism activities.

Bird Sanctuary	Important Bird Species	Important Migratory Bird Species	Other Important Features
Bharatpur Bird Sanctuary (Rajasthan)	Siberian Crane, Painted Stork, Pelicans.	Siberian Crane, Northern Pintail, Common Teal.	UNESCO World Heritage Site, Key stopover for migratory birds.
Sultanpur Bird Sanctuary (Haryana)	Siberian Crane, Greater Flamingo, Sarus Crane.	Northern Shoveler, Ruff, Eurasian Curlew.	Birdwatching facilities, Nature trails, Interpretation center.
Salim Ali Bird Sanctuary (Goa)	Malabar Trogon, Nilgiri Wood Pigeon.	Blue-tailed Bee-eater, Blyth's Reed Warbler.	Mangrove forests, Birdwatching trails, Interpretation center.
Kumarakom Bird Sanctuary (Kerala)	Indian Cormorant, Brahminy Kite, Wood Sandpiper.	Eastern Great Egret, Black-winged Stilt, Common Sandpiper.	Backwater cruises, Birdwatching boat tours, Eco-friendly tourism initiatives.
Vedanthangal Bird Sanctuary (Tamil Nadu)	Spot-billed Pelican, Asian Openbill Stork.	Garganey, Black-tailed Godwit, Common Greenshank.	One of the oldest bird sanctuary in India, Ideal for bird photography, Boating facilities.
Ranganathittu Bird Sanctuary (Karnataka)	Painted Stork, Indian River Tern.	River Tern, Pied Kingfisher, Black-headed Ibis.	River island sanctuary, Boat safaris, Breeding ground for waterbirds.
Nal Sarovar Bird Sanctuary (Gujarat)	Greater Flamingo, Pelicans, Spoonbills.	Bar-headed Goose, Eurasian Wigeon, Eurasian Spoonbill.	Largest wetland bird sanctuary in India, Boating facilities, Rich avian diversity.
Chilika Lake Bird Sanctuary (Odisha)	Osprey, Greater Flamingo, Spoon-billed Sandpiper.	Bar-headed Goose, Eurasian Curlew, Caspian Tern.	Asia's largest brackish water lagoon, Important Ramsar Site, Birdwatching boat tours.
Thattekad Bird Sanctuary (Kerala)	Malabar Grey Hornbill, Sri Lanka Frogmouth.	Sri Lanka Frogmouth, Blue-throated Flycatcher, White-bellied Blue Flycatcher.	Endemic bird species, Dense evergreen forests, Guided birdwatching tours.
Kaziranga Bird Sanctuary (Assam)	Bengal Florican, Great Hornbill, Jerdon's Babbler.	Lesser Whistling Duck, Common Greenshank, Brown-headed Gull.	UNESCO World Heritage Site, Rich grasslands and wetlands, Significant bird diversity.

IMPORTANT BIRD AREAS

Important Bird Areas (IBAs) are specific sites identified around the world as critical for the conservation of bird populations and their habitats. These areas are selected based on standardized criteria developed by BirdLife International, a global partnership of conservation organizations. Here's an overview of Important Bird Areas:

- **Criteria for Identification:**
  - IBAs are identified based on a set of standardized criteria that consider the presence of significant bird populations, threatened or endemic species, and important habitats such as breeding grounds, feeding areas, and migration stopovers.
  - Criteria also include the presence of globally threatened bird species, species with restricted ranges, and congregatory bird concentrations during specific seasons.
- **Global Network:**
  - The IBA program is coordinated by BirdLife International in collaboration with national partner organizations and governments.
  - IBAs form a global network of sites that are crucial for the conservation of birds and biodiversity, with over 12,000 sites identified worldwide.
- **Conservation Importance:**
  - IBAs are recognized as key sites for bird conservation, providing essential habitats for breeding, feeding, and resting for a wide range of bird species.
  - These areas are important not only for birds but also for maintaining overall ecosystem health and functioning, supporting biodiversity, and providing ecosystem services.
- **Management and Protection:**
  - IBAs require effective management and conservation measures to ensure the long-term survival of bird populations and their habitats.
  - Management plans for IBAs often involve habitat restoration, invasive species control, monitoring of bird populations, and engagement with local communities and stakeholders.
  - Many IBAs are legally protected through national parks, wildlife sanctuaries, or other conservation designations, while others rely on voluntary stewardship and community-based conservation initiatives.
- **Examples of IBAs in India:**
  - India has numerous Important Bird Areas, including:
    - Bharatpur Bird Sanctuary in Rajasthan.
    - Kaziranga National Park in Assam.
    - Sundarbans in West Bengal.
    - Corbett Tiger Reserve in Uttarakhand.
- **Challenges and Conservation Efforts:**
  - IBAs face various threats, including habitat loss, degradation, fragmentation, climate change, pollution, and human disturbance.
  - Conservation efforts for IBAs involve a combination of habitat protection, sustainable land use practices, advocacy, education, and community engagement to address these threats and ensure the effective conservation of bird populations and their habitats.

Overall, Important Bird Areas play a crucial role in bird conservation efforts worldwide, serving as focal points for conservation action and raising awareness about the importance of protecting biodiversity and natural ecosystems.

ECO - SENSITIVE ZONE

Eco-Sensitive Zones (ESZs) are designated areas around protected areas such as national parks, wildlife sanctuaries, and tiger reserves, aimed at minimizing the negative impacts of developmental activities on fragile ecosystems and wildlife habitats.

- Typically established within 10 km of the boundary of a protected area, but the extent can vary based on specific ecological needs. Here's an overview of Eco-Sensitive Zones in India:

Purpose and Objectives

- The primary purpose of Eco-Sensitive Zones is to create buffer areas around protected areas to regulate and restrict certain activities that could potentially harm the ecological integrity of these areas. They act as shock absorbers to Protected Areas.
- ESZs help in maintaining ecological balance, protecting wildlife habitats, preserving biodiversity, and ensuring sustainable development in the surrounding regions.

Designation Process

- ESAs are notified by the Ministry of Environment, Forest and Climate Change (MoEFCC) under the Environment Protection Act 1986.
- The governing statute, as outlined in the **National Wildlife Action Plan (2002-2016)** by the Ministry of Environment, Forests and Climate Change (MoEFCC), mandated that **state** governments should designate land within a 10-kilometer radius of national parks and wildlife sanctuaries' boundaries as eco-fragile zones or Eco-Sensitive Zones (ESZs) under the **Environmental (Protection) Act, 1986.**
- Survey and identification of ESZs are conducted by the respective **State** Governments for consideration of the Central Government for declaration of the ESZs in respective States around National Parks and Wildlife Sanctuaries as per the guidelines formulated

by the Ministry of Environment, Forest and Climate Change (MoEF&CC). On the basis of proposals and recommendations of the State Government, **MoEFCC notifies the ESZs.**

- The process involves scientific assessments, mapping of sensitive habitats, and consideration of socio-economic factors.
- Once identified, ESZs are notified under the Environment (Protection) Act, 1986, and specific guidelines are issued for regulating activities within these zones.
- While the EPA of 1986 may not mention eco-sensitive zones explicitly, it provides the legal framework and authority for the government to declare and regulate such zones in accordance with its broader objectives of environmental protection and conservation.
  - Under Section 3(2)(v) of the EPA, the central government has the authority to restrict areas in which industries, operations, or processes shall not be carried out or shall be carried out subject to specific safeguards.
  - This provision gives the government the legal basis to designate specific areas, such as eco-sensitive zones, where certain activities may be regulated or restricted to protect the environment.

Regulations and Activities

- Within Eco-Sensitive Zones, certain activities are regulated or prohibited to minimize disturbances to wildlife, habitats, and ecosystems. These may include mining, quarrying, commercial logging, industrial projects, and construction of large-scale infrastructure.
- Within ten kilometers of protected areas, national parks, and wildlife sanctuaries are found Eco-Sensitive Areas (ESAs).
- Under the Environment Protection Act of 1986, ESAs are notified by the Ministry of Environment, Forests, and Climate Change (MoEFCC).
- To mitigate the adverse impacts of specific activities on the fragile ecosystem surrounding protected areas, the primary objective is to control certain activities in the vicinity of National Parks and Wildlife Sanctuaries.
- Activities: Specific activities are regulated or prohibited within the ESZ, considering potential ecological impacts.
- Activities Prohibited in ESZs:
  - **Commercial mining, stone quarrying, and crushing units:** These activities can cause significant damage to the environment and disrupt wildlife habitats.
  - **Major hydroelectric projects:** These projects can have a large footprint and alter the natural flow of water, impacting aquatic ecosystems.
  - **Handling of hazardous substances:** This poses a risk of pollution and contamination to the environment and wildlife.
  - **Setting up of brick kilns:** These release air pollutants that can harm human health and the environment.
  - **Setting up of polluting industries:** These can release pollutants into the air, water, and soil, damaging the ecosystem.
- **Activities Regulated in ESZs:**
  - **Infrastructure development:** This includes activities like road construction, tourism development, and renewable energy projects. These activities can be allowed with certain restrictions and mitigation measures to minimize their impact on the environment.
  - **Agriculture and forestry:** These activities are essential for livelihoods in many ESZs, but they need to be managed sustainably to avoid deforestation, soil erosion, and overuse of water resources.
  - **Fishing and grazing:** These activities can be allowed with restrictions to ensure they do not harm wildlife populations or damage their habitats.
- **Activities Permitted in ESZs:**
  - **Traditional and sustainable livelihood activities:** These activities, such as collection of non-timber forest products (NTFPs), ecotourism, and handicrafts, can be promoted as they provide income for local communities while conserving the environment.
  - **Research and education:** These activities can help us better understand and conserve the unique ecosystems of ESZs.

It's important to note that the specific restrictions and permissions for activities in ESZs can vary depending on the individual notification for each zone.

Management and Enforcement

- Management of Eco-Sensitive Zones involves collaboration between various government agencies, local authorities, NGOs, and community-based organizations.
- Enforcement of regulations is typically the responsibility of the state forest departments and wildlife authorities, with support from local administration and law enforcement agencies.
- Monitoring and periodic review of ESZs are essential to assess the effectiveness of management measures and address emerging threats or conservation challenges.
- Examples of Eco-Sensitive Zones:
  - Some examples of Eco-Sensitive Zones in India include the ESZs around Kaziranga National Park in Assam, Ranthambore National Park in Rajasthan, Corbett Tiger Reserve in Uttarakhand, and Periyar Tiger Reserve in Kerala.
  - These ESZs serve as critical buffer areas, protecting wildlife habitats, migratory corridors, and watersheds while promoting sustainable development practices in the surrounding landscapes.

The Western Ghats, a **UNESCO World Heritage Site**, are ecologically critical mountains running parallel to India's west coast. The Western Ghats region in India has been recognized as an ecologically sensitive area due to its rich biodiversity and unique ecosystems. Concerns about conserving this ecologically significant region led to the formation of expert committees, notably the Gadgil Committee and the Kasturirangan Committee, to study and make recommendations regarding its protection:

Biodiversity Conservation Committees

- **Madhav Gadgil Committee Report on the Western Ghats:** The Madhav Gadgil Committee Report on the Western Ghats, also known as the Western Ghats Ecology Expert Panel (WGEEP) report, was submitted in 2011. It aimed to address the ecological concerns of the Western Ghats, a mountain range running along the western coast of peninsular India, recognized as a biodiversity hotspot.
  - **Key Recommendations:**
    - **Ecologically Sensitive Zones (ESZs):** The report classified the Western Ghats into different ESZs based on their ecological sensitivity. It recommended designating the entire Western Ghats as an ESA, further divided into three categories with varying levels of restrictions on activities.
    - **Governance:** It advocated for a shift from top-down governance to a bottom-up approach, empowering local communities (Gram Sabhas) in decision-making related to conservation and development activities.
    - **Ban on Activities:** The report recommended restrictions or bans on certain activities deemed detrimental to the environment, such as mining, quarrying, large-scale infrastructure projects, and the use of Genetically Modified Organisms (GMOs).
    - **Western Ghats Ecology Authority (WGEA):** It proposed establishing a dedicated statutory authority to oversee the implementation of the recommendations and coordinate conservation efforts across different states.
- **Kasturirangan Committee on the Western Ghats:** The Kasturirangan Committee on the Western Ghats, officially known as the High Level Working Group on Western Ghats, was constituted by the Government of India in August 2012. It was chaired by Dr. K. Kasturirangan and was formed to assess the status of the Western Ghats and recommend measures for their conservation and sustainable development.
  - **Recommendations of the Kasturirangan Committee:**
    - The committee recommended that around 37% of the total area of the Western Ghats, roughly 60,000 square kilometers, be declared as Eco-Sensitive Areas (ESAs).
    - The report recommended promoting activities like sustainable agriculture, organic farming, ecotourism, and traditional knowledge systems within the ESAs.
    - The committee recommended a blanket ban on mining, quarrying, setting up of red category industries (highly polluting industries), and thermal power projects within the ESAs.
    - The report emphasized the importance of involving local communities in the decision-making process related to the management of the Western Ghats.

The government is actively conserving biodiversity through focused approaches recommended by various committees.

Eco-Sensitive Zones play a vital role in balancing conservation priorities with the socio-economic needs of local communities, ensuring the long-term sustainability of protected areas and the ecological services they provide. Proper planning, stakeholder engagement, and effective management are essential for the success of ESZs in India.

MARINE PROTECTED AREA

- IUCN defines Marine Protected Area (MPA) as "any area of intertidal or sub tidal terrain, together with its overlaying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment".
- India has established numerous Marine Protected Areas (MPAs) aimed at conserving and effectively managing its coastal and marine ecosystems, thus preserving biodiversity and promoting sustainable fisheries.
- These MPAs, totaling 31 in number, are designated under the **Wildlife (Protection) Act, 1972,** comprising a variety of national parks and wildlife sanctuaries. These designated areas encompass some of India's most diverse coastal habitats.
- For instance, the Marine National Park and Marine Sanctuary located in the Gulf of Kutch are integrated as a singular MPA unit. Similarly, Bhitarkanika National Park and Bhitarkanika Sanctuary together form another MPA. Despite their ecological significance, these MPAs account for less than 4.01% of the total protected area across the country.

Purpose and Objectives

- The primary objectives of MPAs in India include conserving marine biodiversity, maintaining ecosystem health and resilience, supporting sustainable fisheries, and promoting scientific research and monitoring.

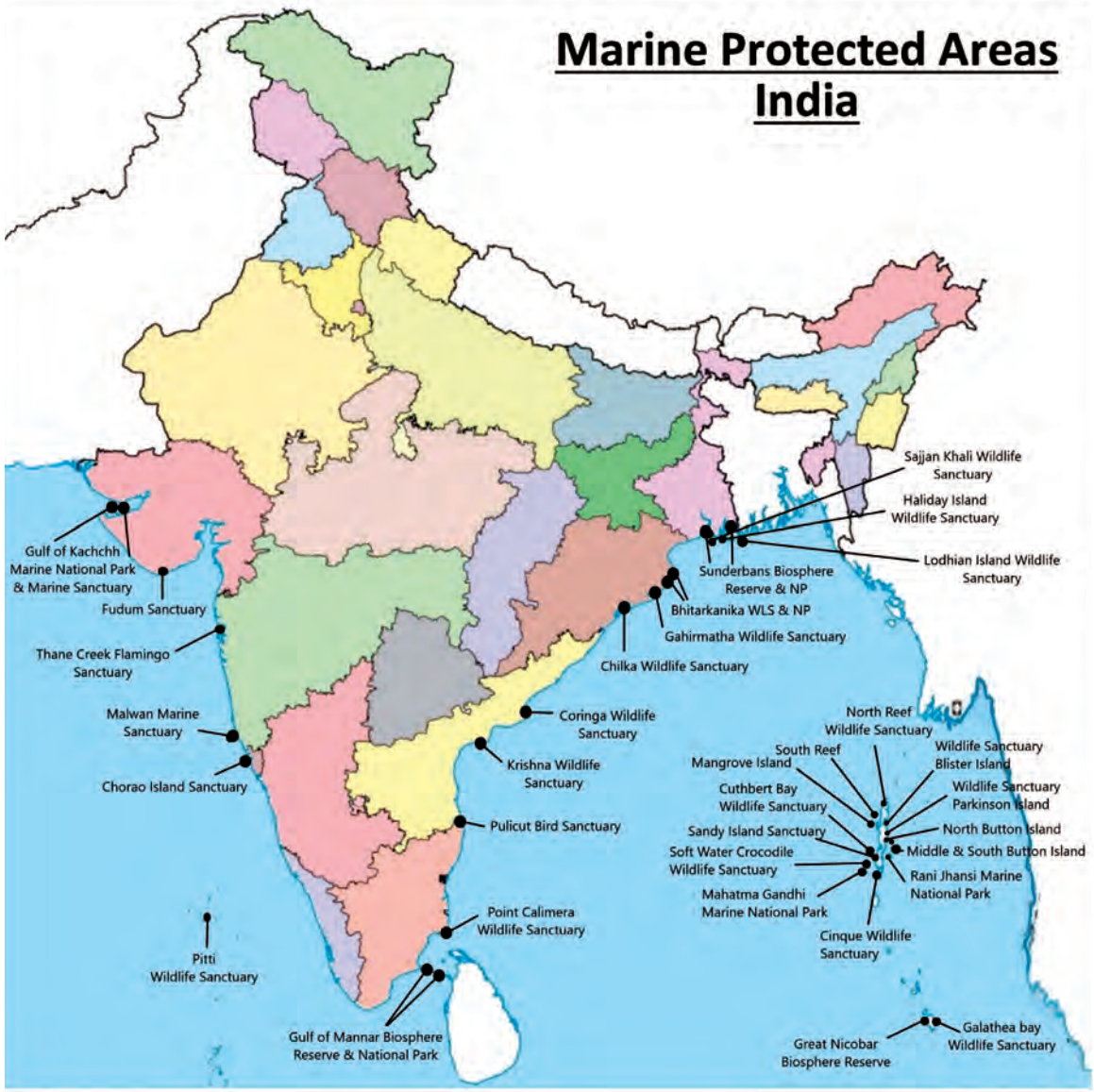


Fig. 7.8: Marine Protected Areas of India

Types of Marine Protected Areas

Types	Description	Examples
Marine National Park	Areas of high biodiversity or unique ecological features designated for strict protection and minimal human disturbance.	Gulf of Kachchh Marine National Park, Gulf of Mannar Marine National Park.
Marine Wildlife Sanctuaries	Similar to national parks, these areas focus on protecting specific species, habitats, or ecological processes. Allow some regulated activities like fishing and traditional practices.	Gahirmatha Marine Sanctuary, Wandoor Marine Sanctuary.
Marine Conversation Reserves	Established to conserve and manage coastal and marine ecosystem while allowing for sustainable us by local communities. Managed by local communities with support from government agencies.	Campbell Bay Community Reserve, Vedaranyam Community Reseve.
Marine Protected Areas	Various types of MPAs established for specific conservation objectives, such as coral reef protection, mangrove conservation, or seagrass bed preservation.	Coral Reef Marine Protected Area, Mangrove Marine Protected Area.

Management and Regulation

- Marine Protected Areas in India are governed by the Wildlife (Protection) Act of 1972, with amendments and additional regulations specific to marine environments.
- Management plans for MPAs are developed by relevant authorities, including the Ministry of Environment, Forest and Climate Change (MoEFCC), state forest departments, and coastal zone management authorities.
- Regulations within MPAs may include restrictions on fishing, boating, tourism, and other human activities to minimize impacts on marine ecosystems and species.

Community Engagement and Stakeholder Participation

- Effective management of MPAs often involves collaboration with local communities, fisherfolk, NGOs, and other stakeholders.
- Community-based conservation initiatives, participatory decision-making processes, and sustainable livelihood programs are integral to the success of marine protected areas.

Significance of MPAs in India

- Biodiversity Conservation: Protect marine habitats and vulnerable species like whales, dolphins, sea turtles, and coral reefs.
- Fisheries Management: Promote sustainable fishing practices by protecting breeding grounds and reducing overfishing.
- Coastal Protection: Buffer shorelines against erosion and natural disasters.
- Livelihoods: Support coastal communities through sustainable tourism and responsible fishing practices.
- Research and Education: Provide valuable opportunities for marine research and environmental education.

Marine protected areas are critical for safeguarding India's rich marine biodiversity and supporting coastal communities. Understanding their various types, significance, and ongoing challenges is crucial for promoting informed conservation efforts and ensuring the health and sustainability of these vital ecosystems.

IGNITE YOUR MIND

Underwater Symphony: Imagine you're a marine biologist studying a newly established underwater reserve. What unexpected discoveries might you encounter in this hidden world?

COASTAL REGULATION ZONES

Coastal Regulation Zones (CRZ) are areas along the coastlines of India that are regulated and managed to balance developmental activities with the conservation and protection of coastal ecosystems, habitats, and communities. Here's an overview of Coastal Regulation Zones in India:

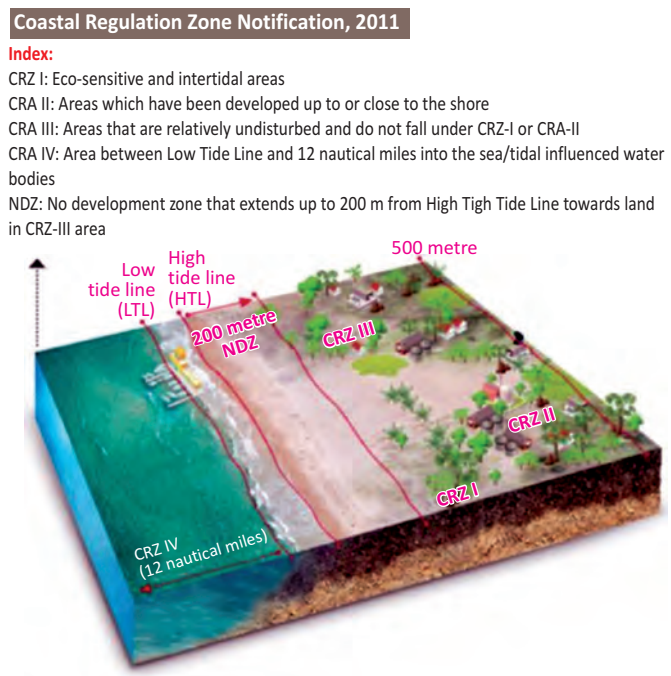

Coastal Regulation Zone Notification, 2011
Index:
CRZ I: Eco-sensitive and intertidal areas
CRA II: Areas which have been developed up to or close to the shore
CRA III: Areas that are relatively undisturbed and do not fall under CRZ-I or CRA-II
CRA IV: Area between Low Tide Line and 12 nautical miles into the sea/tidal influenced water bodies
NDZ: No development zone that extends up to 200 m from High Tigh Tide Line towards land in CRZ-III area
500 metre
Low tide line (LTL)
High tide line (HTL)
200 metre NDZ
CRZ III
CRZ II
CRZ I
CRZ IV (12 nautical miles)

Fig. 7.9: Coastal Regulation Zone as per 2011 Notification
Coastal Regulation Zones (CRZs) are Notified by the Central Government under the Environment Protection Act, 1986.

Purpose and Objectives

- The primary purpose of Coastal Regulation Zones is to regulate developmental activities in coastal areas to protect and conserve fragile ecosystems, biodiversity, and coastal communities.
- CRZ regulations aim to minimize environmental degradation, coastal erosion, and natural disasters while promoting sustainable coastal development and livelihood opportunities for coastal communities.

Classification of Coastal Regulation Zones

- The Coastal Regulation Zone Notification, first issued in 1991 and subsequently amended, classifies coastal areas into different zones based on their ecological sensitivity, socio-economic factors, and development pressures.
- Numerous revisions were incorporated into the CRZ 1991 notification, which were then consolidated and released as the CRZ 2011 notification. This updated notification addressed the concerns raised during the implementation of the CRZ 1991 regulations.
- In December 2018, the Union cabinet sanctioned the Coastal Regulation Zone (CRZ) Notification, 2018. This latest notification was formulated based on the

recommendations of the Shailesh Nayak committee, which was established by the Ministry of Environment, Forest and Climate Change (MoEFCC) in June 2014.

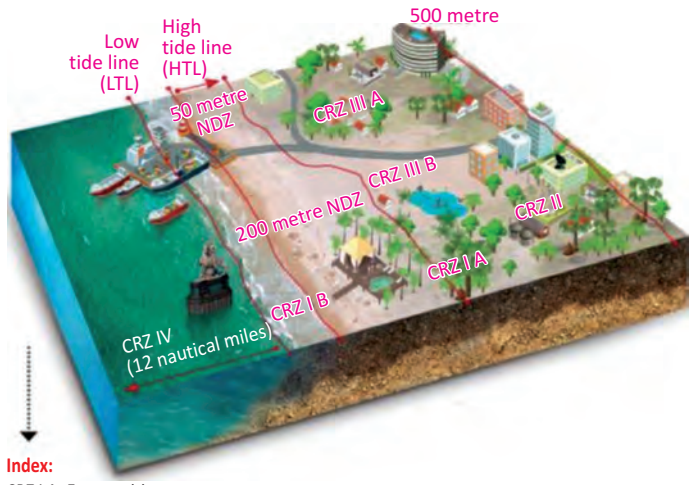
- The committee was tasked with conducting a comprehensive assessment of the provisions outlined in the CRZ 2011 notification, as per the requests from various coastal states/union territories (UTs) and other stakeholders.

❑ **Classification of Coastal Zones under CRZ Notification 2011:**

- **CRZ-I (Ecologically Sensitive Areas):**
  - ❒ No new construction allowed, except for specific projects like those related to the Department of Atomic Energy and trans-harbour sea links.
  - ❒ Permitted activities between Low Tide Line (LTL) and High Tide Line (HTL) in non-sensitive areas include exploration of natural gas, construction of basic amenities, salt harvesting, desalination plants, and storage of non-hazardous cargo within notified ports.
- **CRZ-II (Developed Areas):**
  - ❒ Buildings permissible on the landward side of the hazardous line.
  - ❒ Activities such as desalination plants permitted as per guidelines specified by the notification.
- **CRZ-III (Undisturbed Areas):**
  - ❒ No Development Zone (NDZ) between 0-200 meters from HTL, where no construction is allowed.
  - ❒ Permitted activities include agriculture, forestry, projects of Department of Atomic Energy, mining of rare minerals, salt manufacture, regasification of petroleum products, non-conventional energy sources, and certain public facilities.
  - ❒ Between 200-500 meters from HTL, activities permitted in the 0-200 meters zone, along with construction of houses for local communities and tourism projects.
- **CRZ-IV (Aquatic Area):**
  - ❒ No restrictions on traditional fishing by local communities.
  - ❒ Prohibition on untreated sewage or solid waste dumping in these areas.

❑ **New Rules under CRZ Regulations 2018:**

- Two separate categories for CRZ-III (Rural) areas have been introduced.
- In densely populated rural areas (CRZ-IIIA), the no-development zone is reduced to 50 meters from the high-tide level.
- Rural areas with lower population density (CRZ-IIIB) maintain a no-development zone of up to 200 meters from the high-tide line.
- Islands close to the mainland coast and backwater islands in the mainland now have a no-development zone of 20 meters.



Index:
CRZ I A: Eco-sensitive areas
CRZ I B: Inter-tidal areas
CRA II: Areas which have been developed up to or close to the shore
CRA III A: CRZ-III areas, where the population density is more than 2,161 sq km as per 2011 Census
CRZ III B: Areas with population density of less than 2,161 per sq. k, as per 2011 Census
CRA IV A: 12 nautical miles from the Low tide line towards the sea
CRZ IV B: Tidal influenced water bodies
NDZ: 50 metres from High Tide Line in CRZ III A areas, 200 m from HTL in CRZ-III B areas

Fig. 7.10: Coastal Regulation Zone as per 2018 Notification

High Tide Line (HTL): The high tide line refers to the point on the shore or coastline that marks the maximum height reached by a rising tide. It is the boundary between land and water during high tide, when the water level is at its peak.

Low Tide Line (LTL): The low tide line is the opposite of the high tide line and represents the lowest point reached by a receding tide. It marks the boundary between land and water during low tide, when the water level is at its lowest.

Spring Tide Line: The spring tide line refers to the point on the shore where the highest and lowest tides occur during the lunar month. It occurs when the gravitational forces of the sun and the moon align, resulting in maximum tidal range. Spring tides typically occur during the full moon and new moon phases.

Regulations and Activities

❑ Developmental activities within CRZs are regulated based on the specific restrictions and permissions outlined for each zone.

❑ CRZ regulations restrict or prohibit activities such as construction of new buildings, industries, mining, and disposal of untreated waste in ecologically sensitive areas.

❑ Certain permissible activities may include tourism, fishing, and traditional livelihoods, subject to clearance from the Coastal Zone Management Authorities and adherence to specified guidelines.

Management and Enforcement

- The National Coastal Zone Management Authority (NCZMA) at the federal level, the State/Union Territory Coastal Zone Management Authorities (SCZMAs/UTCZMAs) in each coastal State and Union Territory, and the District Level Committees (DLCs) in each district with a coastal stretch and where the CRZ notification is applicable are the three organisations in charge of putting the CRZ into practice.
- Enforcement of CRZ regulations is essential to prevent unauthorized activities and ensure adherence to prescribed norms, with penalties for violations as per the Coastal Regulation Zone Notification.

Coastal Regulation Zones play a crucial role in protecting India's coastal ecosystems, biodiversity, and cultural heritage while promoting sustainable development and resilience to climate change impacts. Effective implementation, stakeholder engagement, and adaptive management are essential for the success of CRZ regulations in safeguarding India's coastal zones.

SACRED GROVES IN INDIA

Sacred Groves are patches of forest that are protected by communities due to their religious, cultural, or spiritual significance. These groves serve as important repositories of biodiversity and are considered sacred by local communities, who protect them from human exploitation and development.

- Sacred groves have been legally protected under 'community reserves' in the Wildlife (Protection) Amendment Act, 2002. Hunting and logging are usually strictly prohibited within these patches.

Here's an overview of Sacred Groves in India:

- **Cultural and Spiritual Significance:**
  - Sacred Groves have deep-rooted cultural and religious significance in India, dating back centuries. They are often associated with deities, spirits, or ancestral worship, and rituals and ceremonies are performed within these groves.
  - These groves are considered sacred by local communities, who believe that they are inhabited by divine beings and possess spiritual energy. As a result, they are protected from deforestation, hunting, and other human activities.
- **Biodiversity Hotspots:**
  - Sacred Groves are biodiversity hotspots, harboring a wide range of plant and animal species, including many endemic and threatened species.
  - These groves often represent remnants of natural ecosystems in heavily modified landscapes, providing habitat for rare and endangered species and serving as important genetic reservoirs.
- **Conservation Practices:**
  - Conservation of Sacred Groves is primarily driven by religious and cultural beliefs, with communities actively participating in their protection and management.
  - Traditional conservation practices, such as taboos against cutting trees or harming wildlife, are followed within these groves, ensuring their long-term preservation.
  - Local communities often appoint custodians or priests to oversee the management of Sacred Groves and enforce traditional rules and regulations.
- **Examples of Sacred Groves in India:**
  - **Khasi and Jaintia Hills (Meghalaya):** Law kyntangs, community-protected groves associated with each village.
  - **Aravali Hills (Rajasthan):** Bishnoi community's revered neem trees and their tradition of protecting them.
  - **Western Ghats (Karnataka):** Kavus, small sacred groves harboring diverse plant and animal life.
  - **Chanda and Bastar (Madhya Pradesh):** Sarna tribal communities' sacred groves dedicated to local deities.
- **Challenges and Threats:** Despite their cultural significance, Sacred Groves face threats from anthropogenic activities such as urbanization, agricultural expansion, logging, and encroachment.
  - Changing socio-economic dynamics and modernization have led to a decline in traditional beliefs and practices, posing challenges to the conservation of Sacred Groves.
  - Climate change and invasive species also pose threats to the ecological integrity of these groves, altering their composition and structure.
- **Conservation Efforts:**
  - Efforts are underway to conserve and revive Sacred Groves through community-based initiatives, scientific research, and policy interventions.
  - Non-governmental organizations, government agencies, and local communities are collaborating to raise awareness, document traditional knowledge, and implement sustainable management practices.
  - Recognition of the cultural and ecological importance of Sacred Groves is increasing, leading to the formulation of policies and programs aimed at their conservation and restoration.

Sacred Groves play a crucial role in biodiversity conservation, cultural heritage preservation, and sustainable livelihoods in India. By recognizing their significance and engaging local communities in their conservation, these unique ecosystems can be safeguarded for future generations.

IGNITE YOUR MIND

The Ethical Maze: Conservation efforts sometimes pit conservation goals against cultural practices of local communities. How can we navigate this ethical dilemma to find a win-win solution that respects both nature and tradition?

WORLD HERITAGE SITES

World Heritage Sites (WHS) are cultural, natural, or mixed properties that are recognized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as having outstanding universal value. These sites are considered to be of immense importance to humanity and are protected and preserved for future generations. Here are some key aspects of World Heritage Sites:

Criteria for Selection

- To be inscribed on the UNESCO World Heritage List, a site must meet one or more of the ten selection criteria, which are divided into cultural, natural, and mixed categories.
- Cultural criteria include the site's representation of human creativity, cultural interchange, or architectural significance, while natural criteria focus on exceptional natural beauty, geological features, or biodiversity.
- Mixed criteria are applied to sites that possess both cultural and natural values of outstanding universal significance.

Nomination Process

- The nomination of a site for World Heritage status typically begins at the national level, with governments identifying and preparing a tentative list of potential sites within their territory.
- Once a site is nominated, it undergoes a rigorous evaluation process by UNESCO's World Heritage Committee, which assesses its significance, integrity, and management.
- If the site meets the criteria and demonstrates effective protection and management measures, it may be inscribed on the World Heritage List.

Protection and Management

- World Heritage Sites benefit from international recognition and support, which helps raise awareness and funding for their protection and conservation.
- Each site has a management plan developed by the respective authorities, outlining strategies for conservation, sustainable development, visitor management, and risk preparedness.
- UNESCO provides technical assistance, capacity building, and funding opportunities to support the conservation efforts of World Heritage Sites.

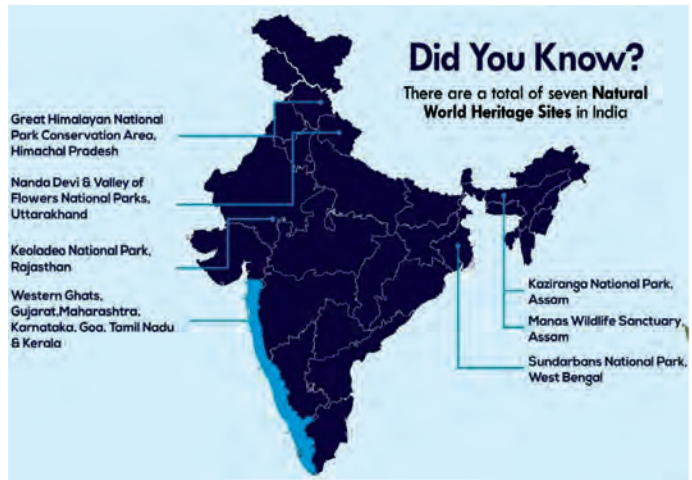

Did You Know?
There are a total of seven Natural World Heritage Sites in India
Great Himalayan National Park Conservation Area, Himachal Pradesh
Nanda Devi & Valley of Flowers National Parks, Uttarakhand
Keoladeo National Park, Rajasthan
Western Ghats, Gujarat,Maharashtra, Karnataka, Goa, Tamil Nadu & Kerala
Kaziranga National Park, Assam
Manas Wildlife Sanctuary, Assam
Sundarbans National Park, West Bengal

Fig. 7.11: Natural World Heritage Sites in India

Types of World Heritage Sites

- Cultural Heritage Sites: These include historic monuments, archaeological sites, urban centers, and cultural landscapes that bear testimony to human civilization and creativity.
- Natural Heritage Sites: These encompass exceptional natural features, ecosystems, and geological formations of universal significance, such as national parks, biosphere reserves, and wilderness areas.
- Mixed Heritage Sites: These are properties that exhibit both cultural and natural values, representing the interaction between humans and their environment over time.

World Heritage Sites in India

India is home to a rich tapestry of cultural and natural heritage, with several sites inscribed on the UNESCO World Heritage List. These sites bear exceptional testimony to the country's history, architecture, art, and biodiversity. Here are some notable World Heritage Sites in India:

Natural Heritage Site

- The Great Himalayan National Park Conservation Area, located in Himachal Pradesh, India, is renowned for its rich biodiversity, housing a diverse range of flora and fauna. This protected area in the Western Himalayas boasts a variety of wildlife including leopards, tigers, elephants, peacocks, hornbills, butterflies, cobras, and snakes, among others.
- Kaziranga National Park, situated in Assam, India, is celebrated as one of the country's most prominent national parks and a UNESCO World Heritage Site. Known for its lush rainforests and remarkable biodiversity, Kaziranga is especially famous for its endangered Indian one-horned rhinoceros population. Additionally, it serves as a Tiger Reserve and provides a habitat for numerous other wildlife species.

- Manas Wildlife Sanctuary, also located in Assam, India, is recognized as one of the nation's vital wildlife sanctuaries. Renowned for its scenic beauty, the sanctuary is home to endangered species such as tigers, swamp deer, greater one-horned rhinos, pygmy hogs, and Bengal floricans.
- Nanda Devi and Valley of Flowers National Parks, situated in Uttarakhand, India, are renowned for their unparalleled beauty and rich biodiversity. These parks harbor a wide array of flora and fauna, including rare birds and animals such as Asiatic black bears, brown bears, snow leopards, and blue sheep. The stunning landscape offers excellent opportunities for hiking, trekking, and immersing oneself in nature's splendor. Valley of Flowers National Park lies completely in the temperate alpine zone.
- Sundarbans National Park, located in West Bengal, India, is a remarkable sanctuary spanning the Ganges delta and boasting the world's largest area of mangrove forests. This extraordinary ecosystem is home to rare species including tigers, reptiles, aquatic mammals, and birds, making it a haven for nature enthusiasts.
- The Western Ghats, stretching across the states of Maharashtra, Goa, Karnataka, Tamil Nadu, and Kerala, are a significant geographical mountain range in India. Designated as a UNESCO World Heritage Site, the Western Ghats are renowned for their unparalleled biodiversity and stunning landscapes. These mountains offer exceptional hiking, biking, and camping opportunities, showcasing the beauty of India's natural heritage.

Mixed Heritage Site

- Khangchendzonga National Park, also known as Kanchenjunga Biosphere Reserve, is situated in Sikkim, India, serving as both a national park and a biosphere reserve. This remarkable site gained recognition on the UNESCO World Heritage Sites list in July 2016, marking it as India's inaugural "Mixed Heritage" site. It was also embraced by the UNESCO Man and the Biosphere Programme. The park derives its name from the towering Kanchenjunga mountain, which stands as the third-highest peak globally, soaring to an impressive height of 8,586 meters (28,169 feet). Covering a vast expanse, the park spans a total area of 1780 square kilometers.

World Heritage Sites represent the diversity of human cultures and natural landscapes across the globe, fostering international cooperation and mutual understanding. They serve as educational and inspirational resources, promoting sustainable development, cultural exchange, and heritage preservation. These sites are cherished as iconic symbols of humanity's collective heritage and are protected for the benefit of present and future generations.

RAMSAR SITES

A Ramsar site refers to a wetland site designated under the Ramsar Convention, an international treaty aimed at conserving and sustainably utilizing wetlands. Wetlands recognized as Ramsar sites are considered of international importance due to their ecological significance, biodiversity value, and the ecosystem services they provide.

- The Ramsar Convention, officially known as the Convention on Wetlands of International Importance, was adopted in the Iranian city of Ramsar in 1971 and came into force in 1975. Its primary objective is to promote the conservation and wise use of wetlands through international cooperation and local actions.
- Countries that are party to the Ramsar Convention designate specific wetland areas within their territories as Ramsar sites based on certain criteria outlined by the convention. These criteria include the presence of rare or unique ecosystems, habitats for endangered species, significant ecological, botanical, zoological, limnological, or hydrological features, and their importance for maintaining biodiversity.
- Once designated as Ramsar sites, these wetlands benefit from international recognition and support for conservation efforts. The designation helps raise awareness about the value of wetlands, encourages sustainable management practices, and facilitates cooperation among countries to protect shared resources.
- Overall, Ramsar sites play a crucial role in safeguarding biodiversity, providing essential ecosystem services such as water purification, flood control, and carbon sequestration, and supporting local livelihoods and cultures dependent on wetland resources.

Ramsar Convention

- The Ramsar Convention on Wetlands is an international treaty aimed at conserving and sustainably using wetlands around the world.
  - Adopted in Ramsar, Iran, in 1971; entered into force in 1975.
  - Aims to protect wetlands' ecological importance and benefits.
  - Objectives:
    - Promote **conservation and wise** use through national and international efforts.
    - List Ramsar Sites and ensure effective management.
    - Encourage research, monitoring, and information exchange.
    - Raise awareness and promote public participation.
  - 172 countries are party to the convention, with over 2,400 Ramsar Sites worldwide.

Ramsar sites of India

The most important ramsar sites of India are as follow:

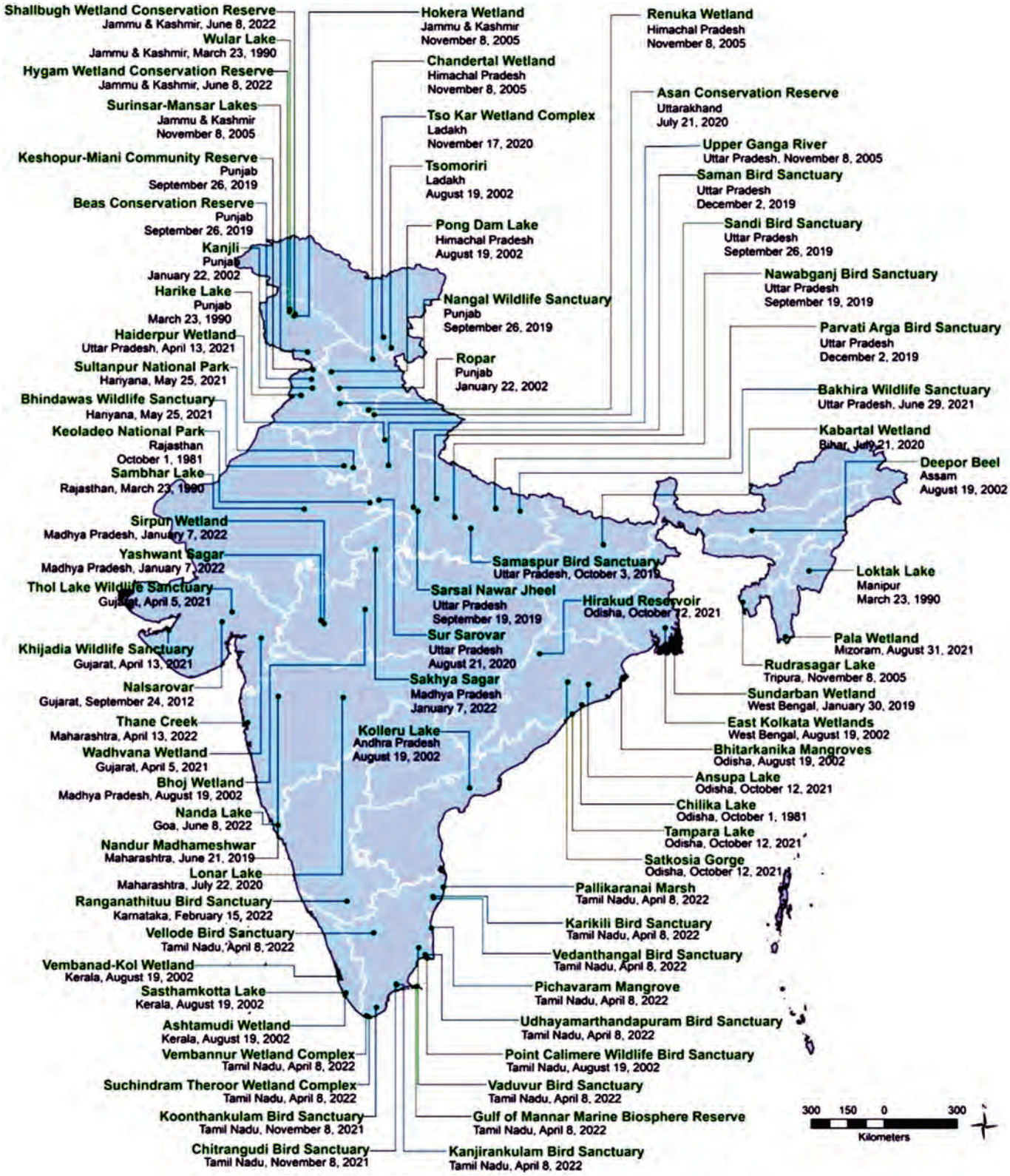


Fig. 7.12: Ramsar Sites of India

- **Chilika Lake, Odisha:** Chilika Lake is Asia's largest brackish water lagoon, spreading over the Puri, Khurda, and Ganjam districts of Odisha. It is known for its rich biodiversity, including various species of fish, crustaceans, and migratory birds. The lake is a crucial habitat for thousands of birds, including flamingos, pelicans, and herons, especially during the winter months. It also supports the livelihoods of local communities through fishing and tourism.

- **Keoladeo National Park, Rajasthan:** Formerly known as Bharatpur Bird Sanctuary, Keoladeo National Park is located in Bharatpur, Rajasthan. It is renowned for hosting over 364 species of birds, including rare and endangered species like the Siberian crane. The park is a UNESCO World Heritage Site and attracts birdwatchers and nature enthusiasts from around the world.
- **Sundarbans Wetland, West Bengal:** The Sundarbans is the largest tidal halophytic mangrove forest in the world, situated in West Bengal and extending into Bangladesh. It is home to the iconic Royal Bengal Tiger, as well as other wildlife such as saltwater crocodiles, Gangetic dolphins, and numerous bird species. The wetland ecosystem of the Sundarbans is vital for maintaining coastal biodiversity and protecting against natural disasters like cyclones.
- **Loktak Lake, Manipur:** Loktak Lake is the largest freshwater lake in Northeast India, located in Manipur. It is famous for its unique floating islands, locally known as phumdis, which are composed of vegetation, soil, and organic matter. The lake supports a diverse range of flora and fauna, including the endangered Manipur brow-antlered deer (Sangai), making it a Ramsar site of international importance.
- **Deepor Beel, Assam:** Deepor Beel is a freshwater lake and bird sanctuary located near Guwahati, Assam. It serves as an important habitat for resident and migratory birds, particularly during the winter months. The wetland ecosystem of Deepor Beel supports a variety of aquatic plants, fish, and reptiles, contributing to the region's biodiversity.
- **Bhoj Wetland, Madhya Pradesh:** Comprising the Upper Lake and Lower Lake in Bhopal, Bhoj Wetland holds immense archaeological and ecological significance. The Upper Lake, also known as Bada Talab, is believed to have been built by King Bhoj of the Paramara dynasty in the 11th century. The wetland supports a diverse range of flora and fauna, including several endemic and migratory bird species. It serves as a vital habitat for resident waterfowl and provides recreational opportunities for locals and tourists.
- Renuka Lake, Himachal Pradesh: Renuka Lake is the largest natural lake in Himachal Pradesh, located in the Sirmaur district. It is revered as a sacred site, with the lake named after the goddess Renuka, revered as the mother of Lord Parshuram. The lake and its surrounding forests are home to a variety of flora and fauna, including several species of birds and mammals. Renuka Lake is also a Ramsar site recognized for its biodiversity conservation efforts and cultural significance.
- Vembanad-Kol Wetland, Kerala: The Vembanad-Kol Wetland is the largest lagoon system in India, situated in the coastal districts of Kerala. It encompasses the Vembanad Lake, India's longest lake, along with associated marshes, mangroves, and backwaters. The wetland supports a rich variety of aquatic life, including fish, crabs, and prawns, and provides livelihoods to local communities engaged in fishing and tourism. It is also an important habitat for migratory birds and serves as a vital flood buffer for the region.
- Wular Lake, Jammu and Kashmir: Wular Lake is one of the largest freshwater lakes in Asia, located in the Bandipora district of Jammu and Kashmir. Despite its ecological importance, Wular Lake faces conservation challenges due to pollution, encroachment, and siltation. Efforts are underway to address these issues and restore the lake's ecosystem, including initiatives to control pollution and promote sustainable development around its shores. The lake supports a variety of aquatic life and provides habitat for migratory birds, making it an important Ramsar site in the region.
- Harike Lake, Punjab: Harike Lake is a man-made reservoir formed by the confluence of the rivers Beas and Sutlej in the Tarn Taran district of Punjab. It serves as an important habitat for migratory birds, particularly during the winter months when thousands of birds flock to the lake from distant regions. Harike Lake also supports a diverse aquatic ecosystem, including fish, turtles, and amphibians. The wetland plays a crucial role in maintaining ecological balance and supporting the livelihoods of local communities engaged in fishing and agriculture.
- Recently, India has expanded its roster of Ramsar sites, elevating the count from 75 to 80 by appointing an additional five wetlands as Ramsar sites. The Ramsar Site certifications were conferred upon the following:
  - Karaivetti Bird Sanctuary, Tamil Nadu
  - Longwood Shola Reserve Forest, Tamil Nadu
  - Magadi Kere Conservation Reserve, Karnataka
  - Ankasamudra Bird Conservation Reserve, Karnataka
  - Aghanashini Estuary, Karnataka

Ramsar sites represent a global commitment to conserving vital wetland ecosystems. Through international cooperation and local action, these sites serve as crucial havens for biodiversity, ensuring the sustainable management of invaluable natural resources for future generation.

ECOTOURISM AND PROTECTED AREAS

Ecotourism represents a novel approach to tourism, emphasizing trips to natural areas while preserving the integrity of ecosystems. Its primary purpose is to promote conservation, generate economic opportunities for local communities, and raise awareness about the importance of protecting natural resources.

- **Guiding Principles**
  - **Environmental Conservation:** Emphasizes the preservation of natural habitats, biodiversity, and ecosystems.

- **Education:** Seeks to educate travelers and the public about the need to protect forests and wildlife.
- **Development:** Aims to support sustainable economic development while benefiting local communities.
- **Cultural Respect:** Promotes respect for different cultures and traditions, fostering cultural exchange and understanding.
- **Research and Monitoring:** Involves ongoing research and monitoring to understand ecological systems and their response to human intervention.

❑ **India's Potential for Ecotourism**

- India's vast Himalayan region offers breathtaking mountain landscapes and unique wildlife experiences.
- The country's extensive coastline stretching over 7,000 kilometers provides ample opportunities for coastal ecotourism activities such as wildlife watching and water sports.
- India boasts both hot and cold deserts, including the Thar Desert and Ladakh, adding to its diversity as an ecotourism destination.
- With the 10th largest forest cover globally, India offers abundant opportunities for eco-friendly adventures like trekking, bird-watching, and exploring biodiverse forests.
- India is home to seven UNESCO-recognized Natural World Heritage Sites, including the Western Ghats and Sundarbans National Park, showcasing its commitment to preserving natural wonders.
- The combination of diverse landscapes, rich biodiversity, and UNESCO-recognized sites makes India an ideal destination for eco-conscious travelers seeking unforgettable encounters with nature.

Types of Ecotourism

Ecotourism encompasses various types of sustainable travel experiences. From nature-based adventures to cultural immersions and voluntourism, each type offers unique opportunities to explore and conserve our planet's natural and cultural heritage. The four main types of ecotourism are:

❑ **Nature-based Ecotourism:** This type involves direct interaction with nature, such as wildlife viewing and nature photography, while ensuring minimal disturbance to the environment.

❑ **Cultural Ecotourism:** This type focuses on local cultures, traditions, and customs, offering tourists the opportunity to engage with community-based tourism activities and cultural tours.

❑ **Adventure Ecotourism:** Combining thrill with sustainability, adventure ecotourism includes activities like sustainable trekking and eco-friendly adventure sports, appealing to responsible consumers and businesses seeking eco-friendly alternatives.

❑ **Voluntourism:** This type combines travel with volunteering for environmental and community causes, involving participation in conservation projects, community development, or environmental clean-up efforts.

These types encompass a diverse range of activities that cater to different interests and preferences of eco-conscious travelers.

IGNITE YOUR MIND

From Tourist Trap to Treasure Trove: Many protected areas struggle with balancing responsible tourism with conservation. Design a campaign that transforms tourists from passive observers to active stewards.

Best Practices

❑ **Khonoma Village, Nagaland:** Known for its pioneering community-based ecotourism, Khonoma Village in Nagaland boasts the Khonoma Nature Conservation and Tragopan Sanctuary. Here, visitors can experience sustainable agriculture, traditional Naga culture, and guided nature walks, contributing to biodiversity conservation and local economic development.

❑ **Chilika Lake, Odisha:** Known as India's largest brackish water lagoon, Chilika Lake is an unconventional ecotourism destination renowned for its biodiversity conservation and sustainable livelihood projects. Visitors can enjoy birdwatching tours, eco-friendly boating, and community-based conservation initiatives, supporting environmental awareness and local livelihoods.

❑ **Havelock Island, Andaman and Nicobar Islands:** Havelock Island stands out for its ecotourism and marine conservation initiatives. Visitors can engage in coral reef restoration, underwater clean-up drives, and educational programs led by local experts. By involving tourists in conservation efforts, Havelock Island promotes responsible tourism while preserving its marine ecosystem.

Way Forward

To address the challenges in the ecotourism sector in India following solutions need to be incorporated:

❑ **Government Leadership and Coordination:** The central government, in collaboration with state governments, should take a lead role in coordinating efforts to develop and promote ecotourism across the country. This includes setting clear policies, guidelines, and regulations for sustainable ecotourism development.

❑ **Stakeholder Engagement and Participation:** Encourage active participation of local communities, indigenous groups, NGOs, and other relevant stakeholders in the decision-making process. Establishing forums for dialogue and consultation will ensure that their perspectives and concerns are taken into account in the planning and management of ecotourism sites.

- **Infrastructure Development:** Develop necessary infrastructure such as eco-lodges, visitor centers, interpretation trails, and waste management facilities at ecotourism sites. Infrastructure should be designed and implemented in a way that minimizes environmental impact and preserves the natural beauty of the area.
- **Marketing and Promotion:** Develop comprehensive marketing strategies to promote ecotourism destinations in India both domestically and internationally. Utilize digital platforms, social media, and tourism fairs to raise awareness about the unique biodiversity and cultural heritage of ecotourism sites.
- **Financial Support and Incentives:** Provide financial support, grants, and incentives to ecotourism enterprises, especially small and medium-sized businesses, to encourage investment in sustainable practices and infrastructure development. Explore partnerships with international financial agencies and organizations to access additional funding sources.

By implementing these strategic measures, India can overcome the challenges facing the ecotourism sector and unlock its full potential as a sustainable and responsible tourism destination. This approach will not only conserve biodiversity and ecosystems but also support local livelihoods and promote cultural exchange.

Green Tourism

Green tourism complements ecotourism by promoting responsible and sustainable practices within the tourism industry. It aims to minimize environmental impact while offering travelers eco-friendly accommodations and experiences. Certification programs and awareness campaigns play a crucial role in promoting green tourism and fostering a culture of sustainability.

- **Challenges in Green Tourism**
  - **Developing Green Destinations:** Selecting specific destinations for green tourism development is crucial. These destinations should prioritize visitor experiences and support the local economy while preserving natural surroundings. Some areas may limit vehicle access to reduce carbon emissions.
  - For instance, in response to the adverse impacts of extensive infrastructure development in Himalayan tourist destinations, there is now a need to transition these areas into green destinations. This involves measures such as restricting vehicular movement and phasing out plastic waste to preserve the pristine beauty of these regions and promote sustainability.
  - **Collaboration Among Stakeholders:** The transformation of India's tourism industry into a green tourism sector necessitates active collaboration among various stakeholders, including local community members, government bodies, NGOs, the tourism industry, tourists, and numerous other groups.
- **Role of the Private Sector:** Corporate India can contribute significantly to sustainability in tourism. Private sector initiatives should focus on reducing carbon emissions, conserving water, minimizing waste, and protecting biodiversity.
  - Encouraging the hospitality sector to utilize its CSR (Corporate Social Responsibility) funds for green tourism initiatives is a positive step. Their expertise in this area can contribute significantly to promoting sustainability and responsible practices in the tourism industry.
- **Greenwashing:** Green tourism term has gained a negative reputation due to businesses using it as a marketing tactic without genuinely reducing their environmental impact, known as greenwashing.
  - Hence implementing comprehensive guidelines and certification programs for green tourism by the government can be a valuable measure to prevent the issue of greenwashing within the industry.
- **Lack of Awareness:** A significant challenge in the green tourism industry is the lack of awareness, both within the tourism sector and among tourists. To address this, integrating awareness elements into campaigns like "Incredible India" and involving schools to educate students early on about the importance of green tourism can play a crucial role in raising awareness and fostering a culture of sustainability.

Way Forward

To address the challenges in the ecotourism sector in India following solutions needed to be incorporated

- **Government Leadership and Policy:** Central and state governments should lead efforts in developing ecotourism by establishing clear policies and regulations for sustainable practices nationwide.
- **Stakeholder Engagement:** Actively involve local communities, NGOs, and indigenous groups in decision-making through dialogue and consultation, ensuring their perspectives are considered.
- **Sustainable Infrastructure:** Develop eco-friendly infrastructure like lodges and waste management facilities at ecotourism sites, minimizing environmental impact and preserving natural beauty.
- **Marketing and Awareness:** Implement robust marketing strategies domestically and internationally using digital platforms and tourism fairs to highlight India's unique biodiversity and cultural heritage in ecotourism destinations.
- **Financial Support:** Provide financial assistance and incentives to ecotourism enterprises, especially SMEs, to promote investment in sustainable practices, and explore partnerships for additional funding opportunities.

By implementing these strategic measures, India can overcome the challenges faced by the ecotourism sector and unlock its full potential as a sustainable and responsible tourism destination. This approach will not only conserve biodiversity and ecosystems but also support local livelihoods and promote cultural exchange.

ISSUES IN PROTECTED AREAS MANAGEMENT

Management of protected areas faces several challenges and issues that need to be addressed to ensure effective conservation and sustainable use of natural resources. Here are some common issues in protected areas management:

- **Habitat Loss and Fragmentation:**
  - Encroachment, deforestation, urbanization, and infrastructure development lead to habitat loss and fragmentation, reducing the size and connectivity of protected areas.
  - Fragmented habitats are less effective in supporting viable populations of wildlife and can increase human-wildlife conflicts.
  - **Example:** In the Western Ghats region of India, significant habitat loss and fragmentation have occurred due to deforestation, agricultural expansion, and urbanization, isolating protected areas like national parks and wildlife sanctuaries.
- **Poaching and Illegal Wildlife Trade:**
  - Poaching for bushmeat, ivory, horns, and other wildlife products continues to threaten endangered species, undermining conservation efforts.
  - Illegal wildlife trade networks operate globally, exploiting protected areas as sources of valuable species and products.
  - **Example:** Kaziranga National Park in Assam, India, is home to the world's largest population of Indian one-horned rhinoceroses. However, persistent poaching for rhino horns poses a significant threat to their survival, despite conservation efforts.

IGNITE YOUR MIND

Nature's Black Market: Poaching and illegal wildlife trade threaten protected areas. Design a clever, tech-powered sting operation to outsmart these criminals.

- **Human-Wildlife Conflict:**
  - Increasing human populations and encroachment into protected areas lead to conflicts between local communities and wildlife.
  - Crop raiding, livestock depredation, and attacks on humans by predators result in negative perceptions of conservation and retaliatory killings of wildlife.
  - **Example:** The Sundarbans Tiger Reserve in West Bengal, India, experiences frequent human-tiger conflicts due to the dense human population living nearby. Attacks on livestock and occasional human encounters with tigers lead to conflicts and negative attitudes towards conservation efforts.
- **Invasive Species and Habitat Degradation:**
  - Invasive species compete with native flora and fauna, disrupting ecosystems and altering habitat structure and composition.
  - Habitat degradation from factors such as invasive species, pollution, overgrazing, and resource extraction reduces the quality of protected areas and threatens biodiversity.
  - **Example:** In the Andaman and Nicobar Islands of India, invasive species like the vine Lantana camara outcompete native vegetation, leading to habitat degradation and loss of biodiversity.
- **Climate Change:**
  - Climate change impacts, including rising temperatures, altered precipitation patterns, sea-level rise, and extreme weather events, pose significant challenges to protected areas.
  - Shifts in species distributions, changes in phenology, habitat loss, and increased vulnerability to wildfires and diseases are some of the effects of climate change on protected areas.
  - **Example:** National parks in the Himalayan region of India, such as Jim Corbett National Park and Gangotri National Park, are vulnerable to climate change impacts like glacial retreat and altered precipitation patterns, affecting habitat suitability for wildlife.
- **Insufficient Funding and Resources:**
  - Many protected areas suffer from inadequate funding, staffing, and resources for effective management and conservation actions.
  - Limited capacity for law enforcement, monitoring, research, infrastructure development, and community engagement hinders the ability to address conservation challenges.
  - **Example:** Periyar Tiger Reserve in Kerala, India, faces challenges due to inadequate funding and resources, hindering conservation efforts such as anti-poaching patrols and habitat restoration.
- **Lack of Community Engagement and Livelihood Alternatives:**
  - Exclusion of local communities from decision-making processes and limited involvement in conservation initiatives often lead to conflicts and resistance to protected area management.
  - Insufficient livelihood alternatives and inadequate benefit-sharing mechanisms can exacerbate poverty and undermine support for conservation.

- **Example:** Buxa Tiger Reserve in West Bengal, India, has experienced conflicts between conservation authorities and local communities over access to forest resources and traditional land rights, highlighting the need for meaningful community engagement and sustainable livelihood alternatives.

❑ **Governance and Policy Gaps:**

- Weak governance structures, corruption, inadequate legal frameworks, and policy inconsistencies hamper effective protected area management.
- Lack of coordination between government agencies, insufficient stakeholder collaboration, and unclear tenure and land rights contribute to management challenges.
- **Example:** Silent Valley National Park in Kerala, India, faced controversy in the 1970s over proposed hydroelectric projects, reflecting governance and policy gaps that led to conflicts between conservationists and proponents of development projects.

Way Forward

Addressing the challenges facing protected areas management requires a multi-faceted approach involving collaboration among governments, conservation organizations, local communities, and other stakeholders. Here's a way forward to resolve these challenges:

❑ **Enhance Habitat Protection and Connectivity:**

- Expand and strengthen protected area networks to encompass larger landscapes and maintain ecological connectivity.
- Implement land-use planning measures that prioritize habitat conservation and minimize fragmentation.
- Restore degraded habitats through reforestation, habitat restoration projects, and sustainable land management practices.

❑ **Combat Poaching and Illegal Wildlife Trade:**

- Strengthen law enforcement efforts to combat poaching and illegal wildlife trade, including increased patrols, surveillance, and intelligence gathering.
- Enhance collaboration between law enforcement agencies, wildlife authorities, and international partners to disrupt wildlife trafficking networks.
- Implement community-based anti-poaching initiatives that engage local communities in wildlife protection efforts and provide incentives for conservation.

❑ **Mitigate Human-Wildlife Conflict:**

- Implement measures to reduce human-wildlife conflict, such as constructing wildlife-proof fences, installing early warning systems, and promoting crop insurance schemes.
- Develop community-based conservation programs that provide alternative livelihoods, education, and awareness to reduce dependence on natural resources and alleviate poverty.
- Foster dialogue and collaboration between conservation authorities, local communities, and stakeholders to address underlying issues and find mutually beneficial solutions.

❑ **Control Invasive Species and Restore Habitats:**

- Implement invasive species management programs to control the spread of invasive flora and fauna and restore degraded habitats.
- Conduct research to identify effective management strategies and prioritize areas for intervention based on ecological importance and conservation priorities.
- Engage local communities in invasive species control efforts through awareness campaigns, capacity building, and incentivized participation.

❑ **Adapt to Climate Change:**

- Develop climate change adaptation strategies for protected areas, including habitat restoration, species translocation, and ecosystem-based approaches.
- Integrate climate change considerations into protected area planning, management, and monitoring processes.
- Collaborate with local communities to build resilience and adaptive capacity through sustainable livelihood diversification and ecosystem-based adaptation measures.

❑ **Secure Sufficient Funding and Resources:**

- Advocate for increased government funding and support for protected area management, including allocations for staff salaries, infrastructure development, and conservation programs.
- Explore innovative financing mechanisms such as public-private partnerships, eco-tourism revenues, and conservation finance initiatives to supplement government funding.
- Strengthen capacity-building efforts for protected area staff, including training in conservation management, law enforcement, and community engagement.

❑ **Promote Community Engagement and Livelihood Alternatives:**

- Foster meaningful participation of local communities in decision-making processes related to protected area management through inclusive governance structures and participatory planning approaches.
- Support community-based conservation initiatives that empower local communities to take ownership of conservation efforts and benefit from sustainable natural resource management.

- Provide alternative livelihood opportunities that are compatible with conservation goals, such as eco-tourism, agroforestry, sustainable agriculture, and non-timber forest products.

❑ **Improve Governance and Policy Frameworks:**

- Strengthen governance structures and regulatory frameworks for protected areas management, including clear delineation of roles and responsibilities among government agencies and stakeholders.
- Enhance transparency, accountability, and integrity in decision-making processes through improved monitoring, evaluation, and reporting mechanisms.
- Foster collaboration and coordination among government agencies, civil society organizations, academia, and local communities to address governance and policy gaps and promote integrated landscape management approaches.

By implementing these strategies in a coordinated and collaborative manner, we can overcome the challenges facing protected areas management and ensure the long-term conservation and sustainable use of natural resources for the benefit of current and future generations.

IGNITE YOUR MIND

The Cost of Conservation: Imagine you're a financial advisor tasked with creating a sustainable funding model for a protected area. Explore innovative solutions that go beyond traditional government grants.

CONCLUSION

In summary, India's protected areas encompass diverse ecosystems, from Biosphere Reserves to National Parks, Wildlife Sanctuaries, Marine Protected Areas, and Biodiversity Heritage Sites. These areas play a crucial role in conserving biodiversity, promoting sustainable development, and preserving cultural heritage. Challenges like habitat loss, poaching, and insufficient resources persist, requiring collaborative efforts for effective management. Moving forward, prioritizing sustainable practices, enhancing community engagement, and strengthening governance frameworks are essential. By addressing these challenges, India can ensure the long-term sustainability of its protected areas, preserving its natural heritage for future generations.

Environment Degradation, Management and Conservation

8

The delicate balance of our planet is being disrupted, triggering a widespread issue known as **environmental degradation.** Environmental degradation, a pressing global concern, encapsulates the multifaceted damage inflicted upon our surroundings by human activities. As we deplete vital resources and contaminate the Earth, the repercussions resonate across ecosystems, imperiling flora, fauna, and the delicate balance of nature. This chapter delves into the intricate web of environmental challenges, encompassing air and water pollution, habitat destruction, and the pervasive impact of waste pollution. Against the backdrop of India's environmental issues, this exploration aims to unravel the layers of environmental degradation, offering insights into its far-reaching consequences and the urgent need for sustainable solutions.

ENVIRONMENTAL DEGRADATION

Environmental degradation refers to the deterioration of the environment due to the depletion of resources like air, water, and soil, as well as the disruption of ecosystems and the loss of biodiversity. It is defined as any undesirable change or disturbance to the environment.

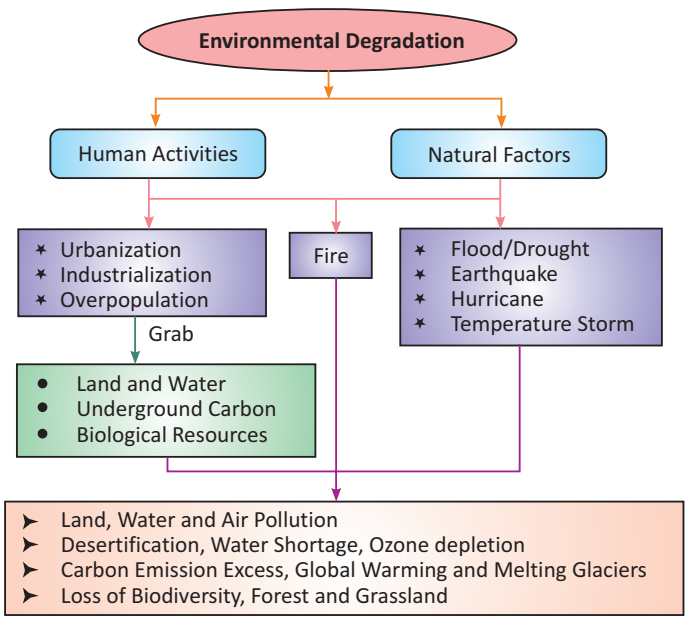


Fig. 8.1: Environmental Degradation

ENVIRONMENTAL DEGRADATION VS ENVIRONMENTAL POLLUTION

Feature	Environmental Pollution	Environmental Degradation
Definition	The introduction of harmful substances or elements into the environment at a rate faster than they can be naturally processed or decomposed.	The long-term reduction in the quality, composition, or capacity of the natural environment to provide goods and services.
Causes	Industrial activities, transportation, agriculture, waste disposal, human activities	Overexploitation of resources, unsustainable practices, climate change, population growth
Types	Air pollution, water pollution, soil pollution, noise pollution, light pollution	Deforestation, desertification, land degradation, biodiversity loss, depletion of natural resources
Impacts	Human health problems, respiratory illnesses, waterborne diseases, ecosystem disruption, climate change	Reduced food security, water scarcity, loss of livelihoods, displacement of communities, reduced biodiversity
Examples	Smog, acid rain, oil spills, plastic pollution	Deforestation, desertification, salinization, soil erosion
Solutions	Reduce, reuse, recycle, renewable energy, sustainable practices, stricter regulations	Conservation efforts, restoration programs, responsible resource management, sustainable development

Environmental pollution and degradation are often interconnected. Pollution can contribute to degradation, and degradation can create conditions that exacerbate pollution. Addressing both issues requires a comprehensive approach that tackles both the sources of pollution and the factors leading to environmental decline.

TYPES OF ENVIRONMENTAL DEGRADATION

Environmental degradation poses significant challenges to ecosystems, biodiversity, and human well-being worldwide.

Environmental degradation can take various forms, each with its own causes, impacts, and implications. Some common types of environmental degradation include:

Type	Description
Pollution	Emission of harmful substances and Discharge of pollutants. Leading to respiratory diseases, acid rain, smog, waterborne diseases, and climate change.
Soil Degradation	Erosion, compaction, salinization, etc., leading to reduced crop yields, desertification, and loss of ecosystem services.
Deforestation	Agriculture, urbanization, logging, etc., causing habitat loss, biodiversity decline, soil erosion, and climate change.
Loss of Biodiversity	Habitat destruction, fragmentation, leading to reduced genetic diversity, disruption of ecosystem services.
Climate Change	Burning fossil fuels, deforestation, etc., causing rising temperatures, sea level rise, extreme weather events.
Land Degradation	Erosion, desertification, salinization, etc., leading to loss of arable land, reduced agricultural yields, and land degradation.
Marine Pollution	Plastic waste, oil spills, etc., causing habitat degradation, biodiversity loss, and harm to marine life.

DEFORESTATION

- According to the Food and Agriculture Organisation(FAO), **deforestation** is defined as the conversion of forest to other land uses due to natural or anthropogenic causes.
- Deforestation occurs worldwide but is particularly prevalent in **tropical regions** such as the Amazon rainforest, Southeast Asia, and Central Africa, where large-scale clearing of forests is done for agriculture, particularly palm oil, soy, and cattle ranching.
- Status of deforestation
  - More than half **(54 percent)** of the world's forests are in only five countries –Russia, Brazil, Canada, the United States of America and China.
  - According to the **State of the World's Forest Report 2020, 10 million hectares(mha)** of forests were lost every year between **2015 and 2020.**

Causes

Natural Causes	Anthropogenic Causes
Forest Fires: Lightning strikes or spontaneous combustion can ignite forest fires, leading to widespread destruction of vegetation and deforestation. **Pest Outbreaks:** Insect infestations and disease outbreaks can kill large numbers of trees, particularly in forests with monocultures or weakened ecosystems.	**Agricultural Expansion:** Clearing forests to make way for agriculture, including large-scale farming, cattle ranching, and cultivation of cash crops such as palm oil, soybeans, and cocoa. **Logging and Wood Harvesting:** Harvesting timber for commercial purposes, including furniture production, construction, and paper manufacturing, contributes to deforestation. **Infrastructure Development:** Construction of roads, highways, dams, urban areas, and industrial facilities often requires clearing forests, leading to habitat loss and fragmentation. **Mining:** Extraction of minerals and resources such as oil, gas, coal, and metals necessitates clearing forests, disrupting ecosystems and causing habitat destruction.
Climate Events: Natural disasters such as hurricanes, tornadoes, landslides, and floods can uproot trees and cause significant damage to forest ecosystems, resulting in deforestation.	**Fuelwood Collection:** Gathering firewood for cooking and heating purposes, particularly in developing countries, contributes to deforestation, especially in rural areas with limited access to alternative energy sources. **Illegal Logging and Land Grabbing:** Unregulated or illegal logging activities, driven by demand for valuable timber species, and land-grabbing practices for agricultural and commercial purposes also contribute significantly to deforestation.

Consequences

- **Loss of Biodiversity:** Deforestation destroys habitats, leading to the loss of plant and animal species. It reduces biodiversity, disrupts ecosystems and diminishes the ability of ecosystems to support diverse and resilient communities of organisms.
  - **The WWF's Living Planet Report 2022** finds wildlife populations have declined by an **average of 69%** in the **past 50 years.**

- **GHG emissions and Climate Change:** Forests act as **carbon sinks,** absorbing carbon dioxide from the atmosphere. Deforestation releases stored carbon back into the atmosphere, contributing to greenhouse gas emissions and exacerbating climate change.
  - According to estimates, **~289 mha** of forests would be deforested in the **tropics** alone between **2016 and 2050.** (State of World's Forest Report 2020).
  - Without corrective actions, this would result in **GHG emissions of 169 $GtCO_2e$.**

  *{The greenhouse gas total is expressed in terms of **gigatonnes of carbon dioxide equivalent per year ($GtCO_2e$/year)**}*
- **Soil Degradation:** Deforestation increases soil erosion, reduces soil fertility, and disrupts nutrient cycles. Loss of vegetation exposes soil to erosion by wind and water, leading to sedimentation in water bodies and degradation of agricultural land. **Example:** Deforestation and mining activities in the **Aravalli Range,** particularly in states like Rajasthan and Haryana, have led to severe soil degradation, leading to loss of topsoil and reduction in soil fertility.
- **Loss of Ecosystem Services:** Forests provide a wide range of ecosystem services, including regulation of water flow, maintenance of soil stability, provision of clean air and water, and climate regulation. Deforestation diminishes these services, affecting human well-being and livelihoods. **Example:** Deforestation in the **Sundarbans,** a UNESCO World Heritage Site and home to the **Royal Bengal tiger,** reduces the forest's capacity to provide protection against cyclones and storm surges, increasing vulnerability for nearby communities.

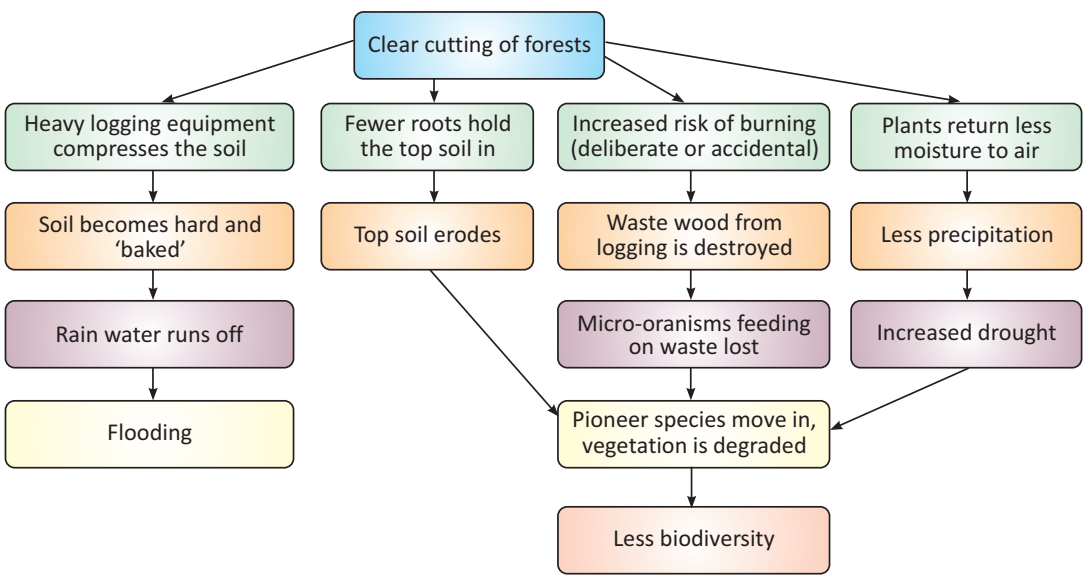

Clear cutting of forests
Heavy logging equipment compresses the soil
Fewer roots hold the top soil in
Increased risk of burning (deliberate or accidental)
Plants return less moisture to air
Soil becomes hard and 'baked'
Top soil erodes
Waste wood from logging is destroyed
Less precipitation
Rain water runs off
Micro-oranisms feeding on waste lost
Increased drought
Flooding
Pioneer species move in, vegetation is degraded
Less biodiversity

Fig. 8.2: Consequences of Deforestation

- **Displacement of Indigenous Peoples:** Deforestation often displaces indigenous communities and traditional forest-dependent peoples, disrupting their way of life, cultural practices, and socio-economic systems. **Example:** The displacement of indigenous tribes like the **Dongria Kondh in Odisha** due to mining activities threatens their traditional way of life and cultural identity.
- **Impact on the Hydrological Cycle:** Forests play a crucial role in regulating the water cycle by influencing precipitation patterns, groundwater recharge, and river flow. **Example:** Deforestation in the **Western Ghats** affects the region's water cycle, leading to reduced rainfall and altered river flows, impacting agriculture and hydroelectric power generation downstream.
- **Loss of Economic Opportunities:** While deforestation may provide short-term economic gains through timber extraction, agriculture, or infrastructure development, it can lead to long-term economic losses by degrading natural resources, reducing ecosystem services, and undermining sustainable development. **Example:** Deforestation in the **Congo Basin** threatens the livelihoods of millions of people who depend on forests for food, shelter, medicine, and income from sustainable forest products.

Case Study: Deforestation in the Amazon Rainforest

- The Amazon Rainforest, often called the **"lungs of the Earth,"** harbors immense biodiversity.
- Cattle ranching in the Brazilian Amazon has been identified as the primary cause of deforestation, accounting for about **80%** of all deforestation in the region.
- Deforestation for agriculture and logging has led to the loss of numerous plant and animal species, including iconic ones like the **jaguar** and the **harpy eagle.**

Way Forward

- **Implement Strict Legal Frameworks:** Enforce existing laws and regulations related to forest conservation and land use planning. Implement stricter penalties for illegal logging, land clearing, and encroachment on forest lands.
  - **Example: India's Forest Conservation Act of 1980** prohibits the diversion of forest land for non-forest purposes without prior approval from the central government.
- **Promote Sustainable Forest Management:** Encourage sustainable forest management practices that balance conservation with economic development. Support community-based forest management initiatives, certification schemes, and forest restoration programs.
  - **Example: The Joint Forest Management (JFM) programme in India** encourages local communities to participate in the management and protection of forest resources.
- **Strengthen Monitoring and Enforcement:** Invest in monitoring technologies such as satellite imagery, drones, and remote sensing to track deforestation activities in real-time.
  - **Example: India's Forest Survey of India (FSI)** utilizes satellite imagery and remote sensing technology to monitor changes in forest cover and detect illegal deforestation activities.
- **Incentivize Reforestation and Afforestation:** Provide financial incentives and technical support for reforestation and afforestation projects. Encourage the establishment of agroforestry systems, urban green spaces, and community forests to increase tree cover and restore degraded lands.
  - **Example: The National Afforestation Programme (NAP) and the Green India Mission (GIM)** are government-led initiatives aimed at increasing forest cover through afforestation and reforestation projects.
- **Address Drivers of Deforestation:** Tackle the underlying drivers of deforestation such as agricultural expansion, infrastructure development, mining, and unsustainable logging.
  - **Example: India's National Mission for Sustainable Agriculture (NMSA)** promotes sustainable agricultural practices to reduce pressure on forest ecosystems.
- **Enhance Collaboration and Partnerships:** Between governments, civil society organizations, indigenous peoples, and the private sector to address deforestation challenges.
  - **Example: The India-UN Development Programme (UNDP) partnership on REDD+ (Reducing Emissions from Deforestation and Forest Degradation)** involves collaboration between the Government of India, UN agencies, civil society organizations, and indigenous communities to address deforestation and promote sustainable forest management.

IGNITE YOUR MIND

Vanishing Forests, Uncertain Futures

Forests, the "lungs of the planet," are disappearing at an alarming rate. Why is deforestation a major environmental concern, and what innovative solutions can we implement to conserve these vital ecosystems?

POLLUTION

Pollution is the introduction of harmful materials called pollutants into the environment.

- **Pollutants** can be **natural,** such as volcanic ash. They can also be created by **human activity,** such as **trash or runoff** produced by factories. Pollutants damage the quality of air, water, and land.
- As per the **World Air Quality Report 2022 by IQAir,** India is the **8th** most polluted country, among **131 countries,** with an **average PM2.5 level of 53.3 µg/m³.**
- According to this report, **Delhi** is the **4th** most polluted city out of 50 **worldwide,** based on **PM2.5 levels.**

Types of Pollution	Causes	Consequences
Air Pollution	Emissions from vehicles, industrial processes, power plants	Respiratory diseases, cardiovascular problems, reduced air quality, acid rain, smog formation, climate change, damage to vegetation and ecosystems
Water Pollution	Discharge of untreated sewage, industrial effluents, agriculture runoff	Contaminated drinking water, waterborne diseases, disruption of aquatic ecosystems, loss of biodiversity, depletion of fish stocks, impaired recreational and economic activities
Soil Pollution	Use of agrochemicals, industrial waste disposal, mining activities	Reduced soil fertility, contaminated food crops, groundwater pollution, health risks for humans and wildlife, soil erosion, degradation of ecosystems
Noise Pollution	Transportation, industrial activities, urbanization	Hearing loss, stress, sleep disturbances, impaired communication, negative impacts on wildlife behavior, decreased quality of life for affected communities

Light Pollution	Artificial sources of light from streetlights, buildings	Disruption of circadian rhythms, sleep disorders, altered behavior in wildlife, interference with astronomical observations, energy wastage
Thermal Pollution	Discharge of heated water from industrial processes, power plants	Reduced oxygen levels in water, disruption of aquatic ecosystems, negative impacts on aquatic organisms, altered water temperature and chemistry
Radioactive Pollution	Nuclear accidents, improper disposal of radioactive waste, nuclear tests	Increased cancer risks, genetic mutations, radiation sickness, contamination of soil, water, and food, long-term environmental damage
Biological Pollution	Introduction of invasive species, pathogens, and genetically modified organisms	Disruption of ecosystems, loss of biodiversity, altered food webs, spread of diseases and pests, ecological imbalance, negative impacts on human health

(**Note:** This aspect will be covered in detail in the next chapter on Pollution.)

CLIMATE CHANGE

- Climate change refers to **long-term shifts in global or regional climate patterns,** primarily attributed to **anthropogenic activities** altering the Earth's atmosphere and surface conditions.
- These shifts can manifest as variations in temperature, precipitation, sea levels, and weather patterns over decades to centuries.
- According to the **IPCC's Special Report on Global Warming of 1.5 °C,** by 2017, human-generated GHG emissions had led to **global warming of 1.0°C** since pre-Industrial levels.

2023 was the Warmest Year on Record (NOAA)

- As per the **National Oceanic and Atmospheric Administration(NOAA),** 2023 was the warmest year since global records began in 1850 by a wide margin.
- It was **1.18 °C** (2.12 °F) above the **20th-century average of 13.9°C** (57.0°F).
- It was **1.35 °C** (2.43 °F) **above the pre-industrial average** (1850-1900).
- The **10 warmest years** in the historical record have all occurred in the past decade **(2014-2023).**

(**Note:***This aspect will be covered in detail in the subsequent chapter on Climate Change*.)

DESTRUCTION OF NATURAL HABITATS AND BIODIVERSITY LOSS

The destruction of natural habitats refers to the alteration, fragmentation, or outright destruction of ecosystems such as forests, wetlands, coral reefs, and grasslands. Biodiversity loss accompanies this destruction, representing the decline in the variety and abundance of species within these ecosystems.

(**Note:**This aspect has been covered in detail in the chapter on Biodiversity.)

LAND/SOIL DEGRADATION

Land or soil degradation refers to the deterioration of soil quality and health, often resulting from unsustainable land management practices, environmental factors, and human activities. This degradation can manifest in various forms, including soil erosion, desertification, salinization, compaction, contamination, and loss of organic matter. According to the **Global Environment Facility** about **25 percent** of the total global land area has been degraded.

Soil degradation **diminishes the soil's ability** to support plant growth, retain water, and provide essential ecosystem services. It can lead to reduced agricultural productivity, increased vulnerability to droughts and floods, loss of biodiversity, and degradation of water quality.

Soil degradation is a subset of land degradation, specifically focusing on the deterioration of soil quality. Land degradation has a broader scope, encompassing various issues affecting the land's productivity.

Feature	Soil Degradation	Land Degradation
Definition	The reduction or loss of the current or future capacity of the soil to provide goods and services	The temporary or permanent reduction or loss of the productive capacity of land
Scope	Focuses specifically on the deterioration of soil quality	Encompasses a broader range of issues affecting the land's productivity, including soil degradation, deforestation, overgrazing, and salinization
Causes	Deforestation, overgrazing, unsustainable agricultural practices, excessive use of fertilizers and pesticides, soil erosion, salinization, and pollution	Similar to soil degradation, but also includes factors like climate change, urbanization, and mining

Impacts	Reduced crop yields, loss of biodiversity, increased soil erosion, water pollution, and desertification	Reduced food security, water scarcity, increased poverty, displacement of communities, and loss of ecosystem services
Examples	Dust storms, desertification, and the salinization of agricultural land	Deforestation, rangeland degradation, and desertification
Solutions	Sustainable land management practices, soil conservation techniques, crop rotation, cover cropping, organic farming, and reducing reliance on chemical inputs	Land use planning, restoration efforts, afforestation, sustainable grazing practices, and integrated water management

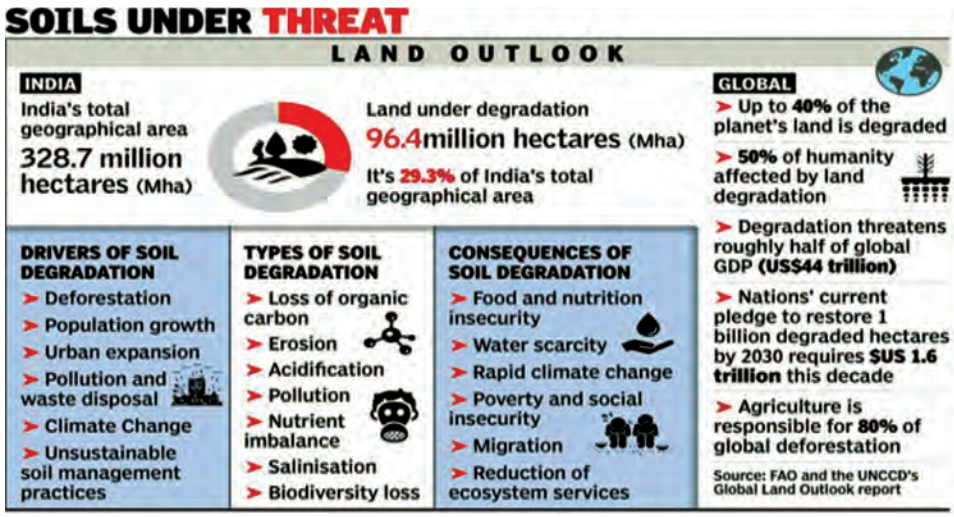


Fig. 8.3: Land or Soil Degradation

Addressing soil degradation requires sustainable land management practices such as conservation agriculture, agroforestry, soil conservation measures, reforestation, and land-use planning to preserve soil health, enhance resilience to environmental stressors, and promote long-term sustainability.

TYPES OF SOIL DEGRADATION

Understanding the types of soil degradation is essential for implementing effective conservation and management strategies to protect soil resources and promote sustainable land use practices.

Soil degradation can be classified into different types **based on:**

- ❑ **Processes causing degradation**
- ❑ **Severity of degradation.**

A. Based on Processes Causing Degradation

Type of Soil Degradation	Description	Causes	Consequences
Physical Soil Degradation	Deterioration of soil structure, texture, and physical properties.	Soil erosion, compaction, loss of soil structure from intensive agriculture, deforestation, and construction activities.	Reduced water infiltration, increased surface runoff, soil compaction, decreased soil fertility and productivity.
Chemical Soil Degradation	Changes in soil chemical properties such as pH, nutrient levels, and contamination by pollutants.	Soil acidification, salinization, nutrient depletion, contamination by heavy metals, pesticides, and industrial pollutants.	Reduced soil fertility, imbalanced nutrient levels, toxicity to plants and soil organisms, degradation of water quality.
Biological Soil Degradation	Loss of soil biodiversity, microbial activity, and organic matter decomposition proc-esses.	Soil erosion, deforestation, overgrazing, monoculture farming, use of chemical pesticides and fertilizers disrupting soil microbial communities.	Reduced soil organic matter content, loss of beneficial soil organisms, decreased nutrient cycling and soil fertility, increased vulnerability to pests and diseases.
Ecological Soil Degradation	Disruption of soil-plant inte-ractions, soil food webs, and ecosystem processes.	Habitat destruction, land use change, invasive species, and climate change altering ecological relationships within soil ecosystems.	Loss of biodiversity, disruption of soil ecosystem functions, decreased resilience to environmental stressors, degra-dation of ecosystem services provided by soils.

B. Based on Severity of Degradation

According to the **Global assessment of soil degradation (GLASOD), four levels** are recognized regarding the degree to which the soil is presently degraded depending on changes in agricultural suitability, declining productivity and its biotic functions.

Severity	Description	Agricultural Suitability	Restoration Possibility	Biotic Functionality
1. Light	The terrain has somewhat reduced agricultural suitability, but is suitable for use in local farming systems. Restoration to full productivity is possible through modifications to the management system. Original biotic functions are still largely intact.	Reduced	Possible	Largely intact
2. Moderate	The terrain has greatly reduced agricultural productivity, but is still suitable for use in local farming systems. Major improvements are required to restore productivity. Original biotic functions are partially destroyed.	Greatly reduced	Required	Partially destroyed
3. Strong	The terrain is non-reclaimable at the farm level. Major engineering works are required for terrain restoration. Original biotic functions are largely destroyed.	Non-reclaimable	Required	Largely destroyed
4. Extreme	The terrain is unreclaimable and beyond restoration. Original biotic functions are fully destroyed.	Non-reclaimable	Beyond restoration	Fully destroyed

These classifications help identify the underlying causes, assess the extent of damage, and guide intervention measures to mitigate soil degradation's adverse impacts.

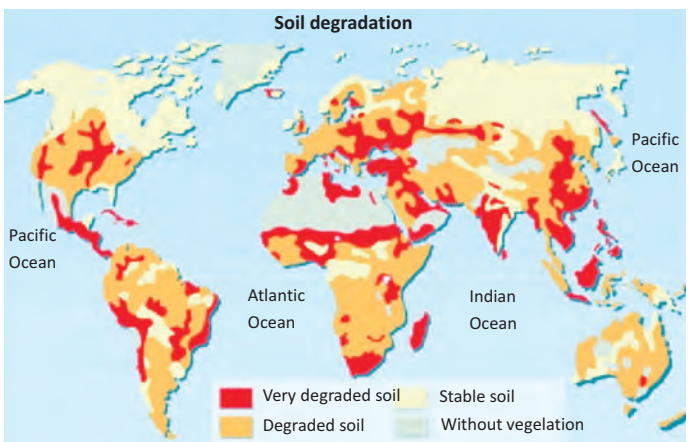


Fig. 8.4: Soil Degradation across the World

Land Degradation at Global Level

- According to UNCCD, between 2015 and 2019, the world lost at least 100 million hectares of healthy and productive land each year, adding up to twice the size of Greenland.
- Eastern and Central Asia, Latin America and the Caribbean regions experience the most severe degradation, affecting at least 20 per cent of their total land area.
- Meanwhile, sub-Saharan Africa, Western and Southern Asia, Latin America and the Caribbean experienced land degradation at rates faster than the global average.
- Notably, in sub-Saharan Africa and in Latin America and the Caribbean, 163 million hectares and 108 million hectares, respectively, have succumbed to land degradation since 2015.

Land/Soil Degradation in India

- Land degradation within **dry land regions (arid, semi-arid and dry sub-humid regions)** is termed as **'desertification'.**
- **97.85 million hectares (29.7%)** of India's total geographical area (TGA) of 328.72 mha underwent land degradation during 2018-19, according to the **Desertification and Land Degradation Atlas of India.**
- Land and soil degradation in India is a significant environmental challenge with far-reaching consequences for agriculture, ecosystems, and livelihoods.

Causes

- **Human Activities:** Human actions such as unsustainable agricultural practices, overgrazing, and land clearing for urbanization and infrastructure development can lead to soil erosion, loss of soil fertility, and degradation of land quality. **Sand mining** along the Indian coasts has led to coastal erosion, saline-water intrusion, destruction of nesting sites for turtles, and the loss of protective barriers against flooding.
- **Industrialization:** Rapid industrial growth often results in pollution from industrial waste and emissions, which can contaminate soil and water, leading to soil degradation and reduced land productivity.
- **Deforestation:** Clearing forests for timber extraction, agricultural expansion, and urban development contributes to soil erosion, loss of biodiversity, and disruption of ecosystems, leading to land degradation and desertification.
- **Pollution:** Pollution from various sources such as industrial effluents, chemical fertilizers, pesticides, and untreated sewage can contaminate soil and water resources, degrading soil quality and harming both terrestrial and aquatic ecosystems.

IGNITE YOUR MIND

Concrete Jungle vs. Urban Oasis

Picture your local park replaced by towering buildings. Explore the multifaceted consequences of unchecked urbanization, considering the loss of green spaces, the strain on resources, and the impact on human well-being.

Impacts of Land/Soil Degradation

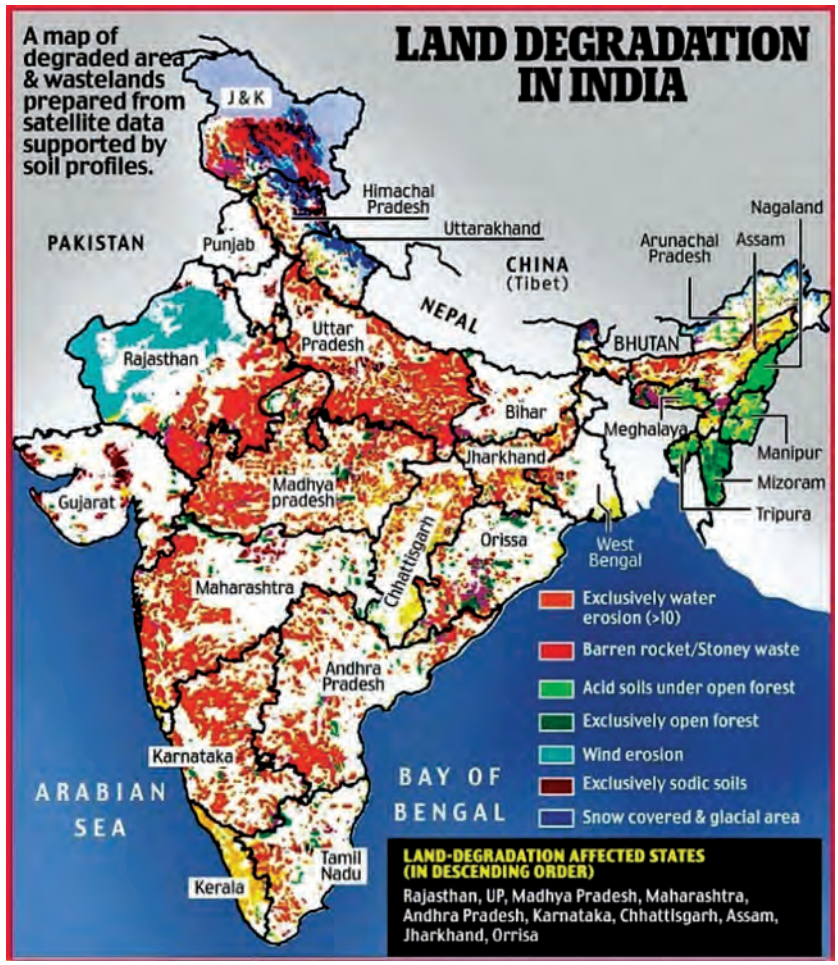


Fig. 8.5: Land Degradation in India

Ecosystems

- Land and soil degradation disrupt ecosystems by altering **soil structure, nutrient cycles, and water retention capacity,** leading to **habitat loss and fragmentation.**
- Degraded lands are less able to support diverse plant and animal species, resulting in **reduced ecosystem resilience and stability.**
- Ecosystem services such as **soil fertility, water purification, and carbon sequestration** are compromised, further exacerbating environmental degradation.

Biodiversity

- Land and soil degradation contribute to the loss of biodiversity by **destroying habitats and reducing the availability of resources** for plant and animal species.
- Reduced biodiversity weakens ecosystems' ability to adapt to environmental changes, increasing the **risk of species extinction** and the **loss of genetic diversity.**
- Degraded soils may become inhospitable to native plant species, favoring the **proliferation of invasive species,** further **disrupting ecological balance.**

Human Health

- Soil degradation can lead to **reduced agricultural productivity, food insecurity, and malnutrition,** particularly in rural communities reliant on subsistence farming.
- Contaminated soils can pose health risks to humans through the **ingestion of toxic substances** present in crops grown on degraded land or through direct exposure to pollutants.

- **Dust and particulate matter** generated from eroded soils can exacerbate **respiratory problems and air pollution,** impacting human health in nearby communities.

Societal and Economic Consequences

- Land and soil degradation undermine livelihoods and **exacerbate poverty,** particularly in regions where agriculture is the primary source of income.
- Degraded lands are less productive and less resilient to environmental stresses, leading to **decreased agricultural yields, income losses, and increased vulnerability to climate change.**
- Soil erosion and land degradation can result in the **sedimentation of water bodies,** affecting water quality, reducing the availability of freshwater resources, and impacting downstream communities and economies.
- The degradation of natural landscapes and the loss of ecosystem services **diminish recreational and cultural values, affecting tourism, aesthetics, and spiritual well-being.**

Methods of Land/Soil Reclamation and Conservation

- **Terracing and Contouring:** Terracing involves creating level platforms on steep slopes to reduce soil erosion and retain water, while contouring involves ploughing and planting crops along the contour lines of the land to minimize soil erosion.
- **Afforestation and Agroforestry:** Planting trees and integrating them into agricultural landscapes through agroforestry practices can help improve soil structure, enhance water retention, and increase biodiversity.
- **Soil Conservation Practices:** Implementing soil conservation practices such as no-till farming, mulching, cover cropping, and crop rotation can help reduce soil erosion, improve soil health, and conserve moisture.

Great Green Wall Initiative (Africa)

- The **Great Green Wall initiative** is a massive project spanning across multiple countries in Africa, aiming to combat desertification and land degradation in the Sahel region.
- It involves planting a wall of trees and vegetation across the continent, from Senegal in the west to Djibouti in the east, covering over 8,000 kilometers.
- By restoring degraded lands, the initiative aims to improve soil fertility, reduce erosion, and provide livelihood opportunities for local communities.
- The project not only contributes to reversing desertification but also helps mitigate climate change by sequestering carbon and enhancing biodiversity.

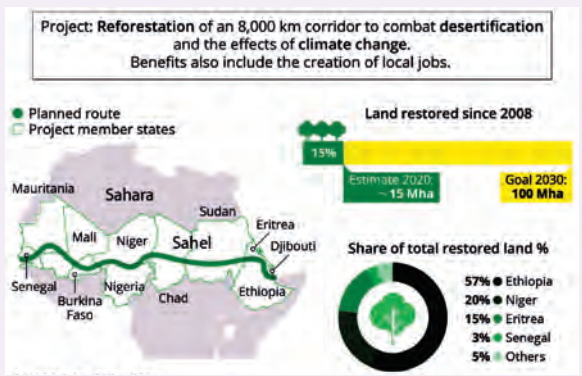


Fig. 8.6: The Great Green Wall Begins to Ries

- **Water Harvesting and Management:** Constructing water harvesting structures such as check dams, ponds, and percolation tanks can help recharge groundwater, reduce soil erosion, and improve water availability for agriculture.
- **Bioengineering and Soil Stabilization:** Using bioengineering techniques such as planting grasses, shrubs, or other vegetation to stabilize slopes, control erosion, and rehabilitate degraded lands.

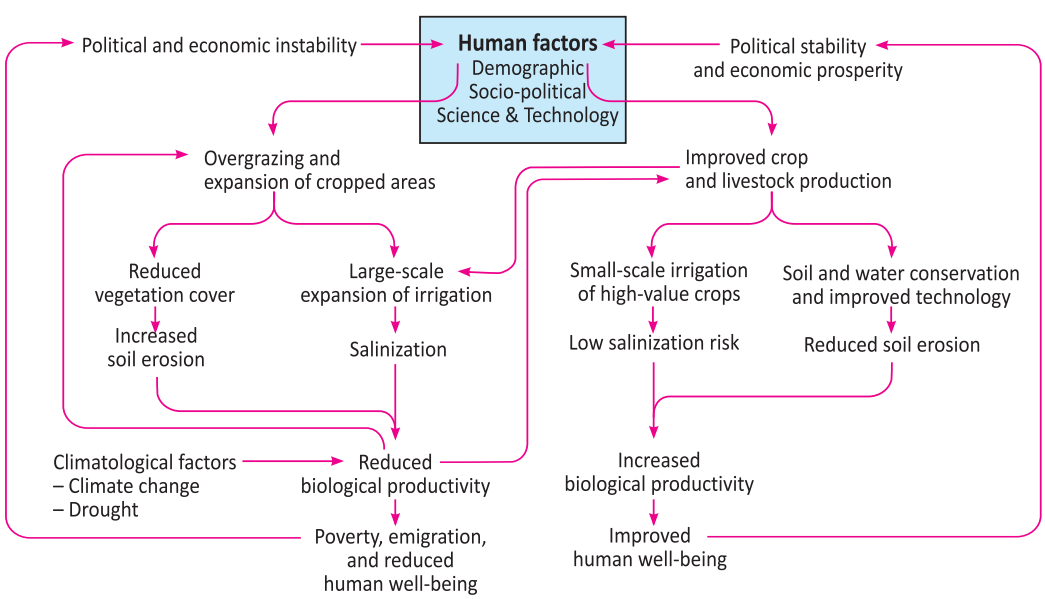


Fig. 8.7: Soil health and Human Well-being

Sustainable Land/Soil Management (SLM)

Sustainable Land/Soil Management (SLM) involves the implementation of practices and techniques that aim to maintain or improve soil quality, productivity, and ecosystem health while minimizing adverse environmental impacts.

Principles of SLM

- **Conservation:** Implementing measures to conserve soil resources and prevent erosion, degradation, and loss of soil fertility. This may involve techniques such as **contour farming, terracing, and no-till agriculture** to reduce soil disturbance and erosion.
- **Improving Soil Health:** Enhancing soil fertility, structure, and nutrient cycling through practices such as **organic farming, cover cropping, and crop rotation.** These practices replenish soil organic matter, improve soil structure, and promote beneficial soil microorganisms.
- **Water Management:** Managing water resources efficiently to prevent soil erosion, waterlogging, and salinization. Techniques such as **mulching, drip irrigation, and rainwater harvesting** help conserve water, reduce runoff, and maintain soil moisture levels.
- **Biodiversity Conservation:** Promoting biodiversity within agricultural landscapes through **agroforestry, crop diversification, and habitat restoration.** Biodiversity enhances ecosystem resilience, pest control, and nutrient cycling, contributing to sustainable land management.
- **Community Engagement:** Involving local communities in decision-making processes, knowledge sharing, and capacity building to promote **sustainable land management practices.** Community participation fosters ownership, resilience, and social equity in land management initiatives.

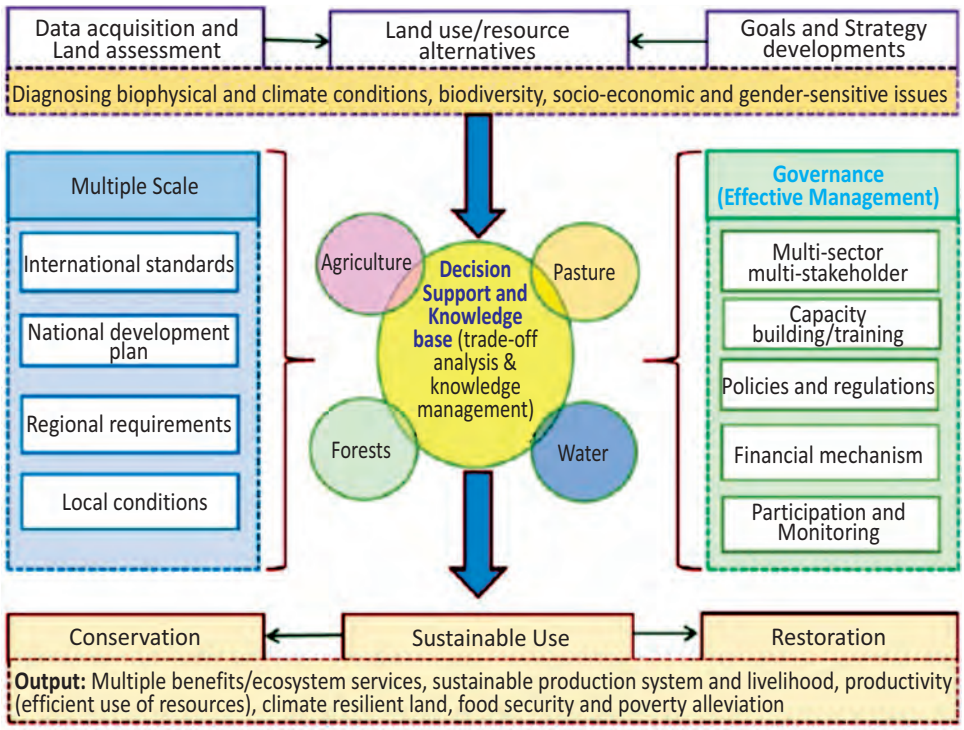


Fig. 8.8: Sustainable Land/Soil Management (SLM)

The Greening of China's Kubuqi Desert

- **The Greening of China's Kubuqi Desert** is a remarkable example of successful desert reclamation and ecological restoration.
- Spanning over **6,000 square kilometers** in the **Inner Mongolia Autonomous Region,** the **Kubuqi Desert** was once plagued by desertification, sandstorms, and land degradation, threatening local livelihoods and ecosystems.
- The greening initiative, launched in the late 20th century, involved a multifaceted approach combining **afforestation, sand fixation, water conservation, and sustainable land management practices.**
- Key interventions included the **planting of drought-resistant vegetation** such as **saxaul trees and shrubs, constructing sand barriers and windbreaks to stabilize dunes,** and implementing **water-saving irrigation techniques such as drip irrigation and mulching.**
- Through concerted efforts by the government, private sector, and local communities, significant progress has been made in reclaiming degraded lands, restoring ecosystems, and improving livelihoods in the Kubuqi Desert.

Land/Soil Degradation Neutrality (LDN)

- According to **UNCCD,** Land/Soil Degradation Neutrality (LDN) is a concept that aims to achieve a **balance between land degradation and land reclamation or conservation efforts.**
- It involves implementing measures to prevent, halt, or reverse land degradation, while also **restoring and rehabilitating degraded lands** to ensure that the overall amount and quality of land resources remain stable or improve over time.
- LDN targets are set at national or subnational levels to track progress towards achieving land degradation neutrality, often as part of broader sustainability goals such as the Sustainable Development Goals (SDGs).

Global Policy Responses to Land/Soil Degradation

- **United Nations Convention to Combat Desertification (UNCCD):** The UNCCD is an international treaty aimed at combating desertification and land degradation, particularly in arid, semi-arid, and dry sub-humid areas. It promotes sustainable land management practices, capacity-building, and international cooperation to address land degradation issues worldwide.
  - **Data:** As of 2023, 197 countries are UNCCD parties, covering over 90% of the world's landmass. An estimated **2 billion hectares** of productive land are degraded, impacting over **3.2 billion people** (UNCCD, 2023, 2021).
- **Sustainable Development Goals (SDGs):** The SDGs include targets related to land degradation, sustainable land management, and biodiversity conservation. Goal 15 specifically focuses on protecting, restoring, and promoting sustainable use of terrestrial ecosystems, including combating desertification, restoring degraded land, and halting biodiversity loss.
  - **Data:** The world is off track to achieve land degradation neutrality by 2030. Over **30% of global agricultural land** is moderately or severely degraded (UNEP, 2023; FAO, 2021).
- **Paris Agreement:** The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) includes commitments from countries to mitigate and adapt to climate change. Enhancing **soil carbon sequestration** and implementing **sustainable land management practices** are important components of climate change mitigation efforts.
- **Great Green Wall:** GEF initiative (2007) in Sahel-Saharan Africa to combat land degradation and restore native plant life.
  - **Progress:** Over **4 million hectares** restored by 2023, surpassing the 2030 target. Improved livelihoods for millions (Great Green Wall Initiative, 2023; World Bank, 2021).
- **Rio Summit (1992):** UNCED recognized land degradation as a challenge, leading to the establishment of UNCCD, UNFCCC, and CBD.
  - **Outcome:** Established key conventions, including UNCCD, UNFCCC, and CBD.
  - **Significance:** Paved the way for global cooperation on environmental issues, addressing land degradation. UNCCD is a direct outcome (Case study).
- **REDD+ (Reducing Emissions from Deforestation and Forest Degradation):** Concept introduced in the early 2000s, aiming to reduce greenhouse gas emissions by addressing forest loss and degradation.
  - **Data:** World Bank studies show REDD+ projects significantly reducing deforestation rates, contributing to biodiversity conservation (World Bank, 2020).
- **Glasgow Leaders' Declaration on Forests and Land Use (COP26, 2021):** Commitment by 141 countries to prevent and reverse the loss of forests and land degradation by 2030 through conservation and restoration efforts.
  - **Data:** Achieving the 2030 target remains challenging, necessitating substantial investment and collective action.

Recent Measures to Address Soil Degradation in India

Schemes

- **Paramparagat Krishi Vikas Yojana (PKVY):** Government of India has been promoting Organic farming in the country through dedicated scheme namely Paramparagat Krishi Vikas Yojana (PKVY) since 2015-16. The scheme stress on end to end support to organic farmers i.e from production to certification and marketing.
- **Sub-Mission on Agriculture Extension (SAME):** Launched in 2015, for promoting **climate-smart agriculture** practices and **soil health management** with a budget of ₹6,928 crore over five years.
- **National Mission on Sustainable Agriculture (NMSA):** Launched in 2014, for promoting various sustainable practices like **conservation agriculture, integrated nutrient management,** and **water conservation** with a budget of ₹36,590 crore over five years.
  - **Data:**
    - A 2022 report by the **National Centre for Organic Farming (NCOF)** shows a **17.45% increase** in certified organic land area in India between 2015-16 and 2021-22.
    - A 2023 report by the **Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW)** indicates a **15% increase** in the adoption of **micro-irrigation techniques** between 2015-16 and 2020-21.

- **Challenges:** Despite these initiatives, challenges remain, including limited awareness among farmers, inadequate infrastructure, and market access issues for organic produce.

- **Soil Health Card Scheme: Launched in** 2015 **with objective of** assessing soil health status and providing customized recommendations for nutrient management. A 2022 study by the **Indian Institute of Soil Science (IISS)** found that soil health card recommendations led to a **10-15% reduction** in fertilizer use in some regions.
- **National Mission for Sustainable Agriculture (NMSA):**
  - **Launched in 2014 with objective to promote climate-resilient** and **environmentally sustainable** agricultural practices.
  - **Data:**
    - A 2023 report by the **Ministry of Agriculture and Farmers Welfare (MoA&FW)** indicates that NMSA has covered over **10 crore hectares** of land under various sustainable practices since its inception.
    - A 2022 study by the **Central Research Institute for Dryland Agriculture (CRIDA)** shows that NMSA interventions have led to a significant reduction in **soil erosion** and improved **water infiltration rates** in targeted areas.
  - **Challenges:** Scaling up successful interventions, ensuring effective reach to small and marginal farmers, and addressing resource constraints at the local level are crucial aspects for further progress.
- **Integrated Watershed Management Program (IWMP):**
  - **Launched:** 1995 **Objective:** Address **soil and water conservation** through community-based watershed development initiatives.
  - **Data:**
    - As of 2023, IWMP has covered over **250 million hectares** of land across India.
    - A 2021 study by the **World Bank** found that IWMP interventions have led to increased **vegetation cover,** improved **soil moisture content,** and reduced **soil erosion** in participating watersheds.
  - **Challenges:** Ensuring long-term sustainability of interventions, community participation, and addressing financial constraints remain key challenges for the program.

Strategies Needed to Address Environmental Degradation

- **Promotion of Sustainable Land Use Practices:** Encouraging sustainable agricultural practices such as conservation agriculture, agroforestry, and organic farming can help reduce soil erosion, improve soil health, and preserve biodiversity.
- **Effective Natural Resource Management:** Implementing integrated watershed management approaches, promoting sustainable forestry practices, and protecting critical ecosystems such as wetlands, mangroves, and coral reefs can help conserve water resources, enhance biodiversity, and mitigate the impacts of climate change.
- **Pollution Control and Waste Management:** Implementing stringent environmental regulations, promoting cleaner production technologies, and investing in pollution control measures can help reduce air, water, and soil pollution. Implementing proper waste management practices such as recycling, composting, and waste-to-energy initiatives can also minimize the environmental impact of waste generation.
- **Climate Change Mitigation and Adaptation:** Implementing measures to reduce greenhouse gas emissions through renewable energy deployment, energy efficiency improvements, and afforestation can help mitigate climate change.
- **Conservation of Biodiversity and Ecosystem Services:** Establishing protected areas, wildlife corridors, and ecological reserves can help preserve biodiversity and maintain essential ecosystem services.
- **Education and Awareness:** Increasing public awareness and education on environmental issues, sustainable living practices, and conservation efforts can foster a culture of environmental stewardship and empower individuals and communities to take action to address environmental degradation.
- **International Cooperation and Policy Integration:** Collaborating with international organizations, sharing best practices, and integrating environmental considerations into national policies and development planning can help address transboundary environmental challenges and promote sustainable development on a global scale.

PREVENTIVE MEASURES TO CURB ENVIRONMENTAL DEGRADATION

- **Afforestation Initiatives:**
  - **Compensatory Afforestation Fund Management Board (CAFMB) Report (2022):** The fund, exceeding ₹44,000 crores, emphasizes the need for improved planning, with only 56% utilized for afforestation, demanding more efficient execution.
  - **National Afforestation Programme (NAP) Progress Report (2023):** While aiming for 5 million hectares by 2030, a significant rise in the annual planting rate is imperative to meet this ambitious target.

- **Rainwater Harvesting:**
  - **Central Ground Water Board (CGWB) Report (2021):** India faces water scarcity in 21 major river basins, and **rainwater harvesting,** proven to reduce groundwater dependence by up to 50%, emerges as a viable solution.
- **River and Water Conservation:**
  - **Water Resources Information System (WRIS) Data (2023):** Declining water levels in numerous rivers, as per WRIS, underline the pressing need for **conservation efforts.**
- **Reduce, Reuse, and Recycle:**
  - **Central Pollution Control Board (CPCB) Report (2022):** India generates over 37,000 tonnes of municipal solid waste daily, making effective **waste management,** through practices like **reduce, reuse, and recycle,** crucial for substantial reduction.
- **Renewable Energy Adoption:**
  - **National Renewable Energy Agency (MNRE) Report (2023):** Despite reaching 167 GW in installed **renewable energy** capacity, India needs to accelerate its transition to meet climate goals.
- **LED Project:**
  - **Energy Efficiency Services Limited (EESL) Report (2022):** Distributing over 350 crore LED bulbs, the LED project has led to an annual energy saving of 47 billion kWh and a CO_2 emission reduction of 38 million tonnes, showcasing the potential of **energy-efficient technologies.**
- **Minimize Fertilizer Use:**
  - **Soil Health Card Scheme (SHCS) Data (2023):** Imbalanced **fertilizer use** contributes to soil degradation and potential health risks. Promoting judicious **fertilizer application** is crucial.
- **Population Control:**
  - **World Population Prospects 2022 (United Nations):** With India's population projected to reach 1.45 billion by 2030, **population control,** combined with other strategies, can be a contributing factor in addressing environmental challenges.
- **Conservation of Endangered Species:**
  - **IUCN Red List of Threatened Species (2023):** With over 400 species in India categorized as **vulnerable, endangered, or critically endangered,** effective **conservation measures** are essential to protect biodiversity.
- **Awareness Campaigns:**
  - **Swachh Bharat Mission (SBM) Gramin (2014):** Successful in increasing awareness about **sanitation** and **waste management,** SBM Gramin demonstrates the impact of targeted **campaigns.**
- **Green Skill Development Programme (2017):**
  - **Ministry of Skill Development and Entrepreneurship (MSDE) Report (2023):** Training over 10 lakh youth, the program has created employment opportunities and promoted **green skills** in various **environmental sectors.**

IGNITE YOUR MIND

Paradise Paradox

You're offered a choice: a life of convenience with advanced technology but constant pollution, or a simpler existence with minimal environmental impact. What factors would influence your decision, and why is finding a sustainable balance crucial?

- **PM PRANAM (2023):**
  - **Ministry of Agriculture and Farmers Welfare (MoA&FW) Report (2024):** In its initial stages, the scheme has the potential to encourage balanced **fertilizer use,** reducing reliance on chemical fertilizers and contributing to **soil health improvement.**
- **Government Regulations:**
  - **National Clean Air Programme (NCAP) Progress Report (2023):** While showing improvement in **air quality** in certain cities, NCAP requires stricter enforcement and long-term strategies for sustained progress.

CONCLUSION

Environmental degradation poses significant challenges to the health of our planet and the well-being of its inhabitants. Human activities, such as industrialization, urbanization, deforestation, and pollution, have led to widespread environmental damage, including the loss of biodiversity, depletion of natural resources, and degradation of ecosystems.

To address these challenges, effective environmental management and conservation efforts are paramount. This requires collective action from governments, businesses, communities, and individuals to implement policies and practices that promote sustainable resource use, reduce pollution, protect habitats, and conserve biodiversity.

By adopting a holistic approach to environmental management and conservation, we can mitigate the impacts of environmental degradation, preserve the integrity of our natural ecosystems, and ensure a sustainable future for generations to come.

Pollution

9

INTRODUCTION

Pollution is the addition of any undesirable substance (solid, liquid or gas)or any form of energy (such as heat, sound, or radioactivity) to the environment at a rate faster than it can be removed (dispersed, diluted, decomposed, recycled, or stored in some harmless form). Pollutants originate from both human activities and natural phenomena like floods, droughts, and earthquakes. These pollutants can be released into the air, water, or soil, disrupting the natural balance and leading to various environmental and health problems.

The sources of pollution are diverse, ranging from industrial emissions and agricultural runoff to vehicle exhaust and improper waste disposal. Pollution disrupts the balance of ecosystems, degrades air, water, and soil quality, and poses significant risks to biodiversity and public health.

With the multidimensional impacts of pollution on the rise, the adoption of sustainable practices and policies to mitigate these impacts is the need of the hour in the 21st century.

TYPES OF POLLUTANTS

Pollutants are external substances that cause harm to the environment. They can be generated from various sources, including industrial processes, transportation, agriculture, and waste disposal. They can be classified into various types based on their existence in nature the form in which they persist, the source of emission and the nature of disposal.

A. Based on Existence in Nature

There are **two** main classifications:

- **Natural Pollutants:** These pollutants originate from natural processes or sources in the environment. Examples include volcanic emissions, pollen, dust, and certain biogenic compounds.
- **Anthropogenic Pollutants:** Anthropogenic pollutants are generated from human activities and industries. Examples include emissions from vehicles, industrial effluents, agricultural runoff, and waste disposal.

Measures to curb these pollutants	
Natural pollutants	**Anthropogenic pollutants**
❑ Establishing **international monitoring networks** to detect volcanic activity and disseminate early warnings to affected regions. ❑ Promoting the use of **native, low-pollen plant species in urban landscaping** and incorporating **green buffers** along highways and construction sites to minimize dust emissions.	❑ Implementing stringent vehicle emission standards such as **Euro 6/VI, BS VI norms** and promoting the adoption of **zero-emission vehicles (ZEVs)** through incentives and subsidies. ❑ Enforcing **pollution control regulations** such as the **Water (Prevention and Control of Pollution) Act, 1974,** and promoting **cleaner production technologies** through incentives and capacity-building programs for industries.

B. Based on the Form in which they Persist

There are **three** main classifications:

- **Persistent Pollutants:**
  - These pollutants remain in the environment for extended periods without breaking down or undergoing significant degradation.
  - Persistent pollutants can **bioaccumulate** in food chains, posing long-term risks to ecosystems and human health.
  - {**Bioaccumulation** is the gradual accumulation of substances, such as pesticides or other chemicals, in an organism. Bioaccumulation occurs when an organism absorbs a substance faster than it can be lost or eliminated by catabolism and excretion}
  - **Examples** include heavy metals like lead and mercury, persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs) and certain pesticides like DDT.
  - **Mitigation Measures**
    - **Heavy metals:** Enforcing international agreements like the **Rotterdam Convention,** which regulates the import and export of **hazardous chemicals,** including certain **heavy metals,** to prevent their unintended release into the environment.
    - **Persistent Organic Pollutants:** Enforcing bans or restrictions on the production, use, and release of POPs through international agreements like the **Stockholm Convention.** Promoting alternatives to POPs in industrial processes, agriculture, and consumer products to phase out their use.

❑ **Non-persistent Pollutants:**

- Non-persistent pollutants are those that degrade relatively quickly in the environment, either through natural processes or treatment.
- Non-persistent pollutants typically have shorter residence times in the environment compared to persistent pollutants.
- **Examples** include Acetone, Benzene, Chlorine and Sulfur dioxide (SO_2).
- **Mitigation Measures**
  - ❒ Promoting the use of cleaner technologies and alternative fuels to reduce emissions of volatile organic compounds (VOCs) and sulfur dioxide.
    - ◊ **Example:** Flex-fuel vehicles (FFVs) are alternative fuel vehicles which have an internal combustion engine and are capable of operating on gasoline and any blend of gasoline and ethanol up to 83%.
  - ❒ Implementing pollution prevention measures such as process optimization and waste minimization will reduce the generation of these pollutants at the source.

❑ **Semi-persistent Pollutants:**

- Semi-persistent pollutants exhibit characteristics of both persistent and non-persistent pollutants.
- They may degrade slowly over time but persist longer than non-persistent pollutants.
- **Examples** include Polycyclic aromatic hydrocarbons (PAHs),Phthalates,Polychlorinated biphenyls (PCBs) and Perfluorooctanoic acid (PFOA).
- **Mitigation Measures**
  - ❒ Implementing recommendations from committees such as the Anupam Verma Committee in India, which provides guidance on strategies to manage pesticide use and reduce environmental contamination, including measures to address semi-persistent pollutants.
  - ❒ Implementing measures to reduce the production and release of semi-persistent pollutants through source control and pollution prevention strategies.
    - ◊ **Example:** Technologies such as soil vapor extraction and bioremediation are employed to reduce pollutant levels and restore site usability of the Love Canal in the United States of America.

C. Based on Source of Emission

There are two main classifications:

❑ Primary pollutants are pollutants directly emitted into the atmosphere from specific sources, such as vehicles, industrial facilities, and natural processes. Examples include:

- **Sulfur dioxide (SO_2), Nitrogen oxides (NOx), Carbon monoxide (CO),**
- **Magnetite particles**
- **Volatile organic compounds (VOCs) and Particulate matter (PM) - PM10 and PM2.5**
- **{PM10 :** Inhalable particles, with diameters that are generally **10 micrometers and smaller.**
- **PM2.5:** Finer inhalable particles, with diameters that are generally **2.5 micrometers and smaller}**
- **Mitigation Measures**
  - ❒ Implementing flue gas desulfurization (FGD) systems in industrial facilities and power plants to remove sulfur dioxide from emissions.
  - ❒ Installing selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) systems in industrial facilities and power plants to reduce nitrogen oxide emissions.
  - ❒ Installing particulate matter control devices, such as electrostatic precipitators (ESPs) and fabric filters, in industrial facilities and power plants.

❑ Secondary pollutants are not directly emitted from a source. They are formed in the atmosphere through chemical reactions involving primary pollutants and other atmospheric compounds. Examples include:

- **Ozone (O_3),** formed through reactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of sunlight.
- **Nitrogen Dioxide (NO_2),** which is formed as NO combines with oxygen in the air.
- **Acid** rain which is formed when sulfur dioxide or nitrogen oxides react with water.
- **Peroxyacyl nitrates or PANs,** which are also referred to as acyl peroxy nitrates or APN, are a component of photochemical smog, produced in the atmosphere when oxidized volatile organic compounds combine with nitrogen dioxide.
- **Secondary particulate matter (PM),** formed through the transformation of gaseous pollutants into solid or liquid particles in the atmosphere.
- **Mitigation Measures**
  - ❒ Stringent regulations on industrial emissions and waste management help prevent the release of precursor pollutants that contribute to secondary pollutant formation.
    - ◊ **Example:** Regulations on volatile organic compound (VOC) emissions from industries help mitigate ozone (O_3) formation.
  - ❒ Agreements such as the Kyoto Protocol and the Paris Agreement aim to reduce greenhouse gas emissions, which contribute to the formation of secondary pollutants like ozone (O_3) and secondary particulate matter (PM).
    - ◊ By committing to emission reduction targets, countries work together to mitigate the impacts of secondary pollutants on air quality and public health.

D. Based on the Nature of Disposal

There are two main classifications:

- Point Source Pollutants: These pollutants originate from specific, identifiable sources such as industrial facilities, sewage treatment plants, and smokestacks.
- Non-point Source Pollutants: Non-point source pollutants come from diffuse sources, making it challenging to pinpoint their exact origins. Examples include agricultural runoff, urban runoff, and atmospheric deposition.

Measures to curb these pollutants

Point Source Pollutants	Non-point Source Pollutants
Implementation of Pollution Control Technologies: **Example:** The installation of electrostatic precipitators (ESPs) in thermal power plants across India has helped reduce the emission of point source pollutants like particulate matter, sulfur dioxide, and nitrogen oxides. Regulatory Compliance: Stringent regulations and enforcement mechanisms can ensure that point sources adhere to emission standards and effluent discharge limits set by environmental agencies. **Example:** National Ambient Air Quality Standards(NAAQS) set by the Central Pollution Control Board (CPCB) mitigate emission levels of point source pollutants. Investment in Infrastructure: Governments and industries can invest in upgrading infrastructure for pollution control, such as upgrading sewage treatment plants, modernizing industrial processes, and retrofitting older facilities with cleaner technologies.	**Best Management Practices (BMPs):** **Example:** In agricultural areas of Punjab, farmers have adopted conservation tillage practices such as zero-till farming and mulching to reduce soil erosion and runoff of pesticides and fertilizers into water bodies. **Land Use Planning:** **Example:** The Chennai Rivers Restoration Trust has implemented land use planning measures, including the creation of buffer zones and wetlands along riverbanks, to minimize urban runoff and pollution entering water bodies in and around Chennai. **Public Education and Outreach:** **Example:** The "I love Yamuna campaign" in Delhi raises awareness among residents about the harmful effects of dumping waste into the Yamuna River and helps in minimizing non-point pollutant discharge.

TYPES OF POLLUTION

The major types of pollution include Air Pollution, Water Pollution, Soil Pollution and Noise Pollution. Other types of pollution are Thermal pollution, Light pollution, Biological pollution and Radioactive pollution.

AIR POLLUTION

- Air Pollution occurs when harmful gases, particulate matter, and other pollutants are released into the atmosphere, often from industrial activities, vehicle emissions, and the burning of fossil fuels.
- Air pollution can lead to respiratory problems, cardiovascular diseases, and environmental damage such as acid rain and smog.
- According to the World Health Organisation(WHO) ambient air pollution and household air pollution is responsible for 6.7 million premature deaths every year. Nine out of ten people now breathe air that exceeds the WHO's pollution guideline levels.

Major Air Pollutants

Particulate Matter (PM)

- Particulate matter refers to tiny particles suspended in the air, consisting of a mixture of solid particles and liquid droplets.
- PM is categorized based on size:
  - **PM10** (particles with a diameter of 10 micrometers or smaller)
  - **PM2.5** (particles with a diameter of 2.5 micrometers or smaller).
- Sources of particulate matter include vehicle emissions, industrial processes, construction activities, agriculture, and natural sources such as wildfires and dust storms.
- PM can penetrate deep into the respiratory system, causing respiratory problems, cardiovascular diseases, and other health issues. Long-term exposure to PM is associated with reduced lung function, lung cancer, and premature death.

Nitrogen Oxides (NOx)

- Nitrogen oxides are a group of gases composed primarily of nitrogen dioxide (NO_2) and nitrogen oxide (NO).
- Sources of NOx include vehicle emissions, industrial combustion processes, power plants, and agricultural activities.
- NOx contributes to the formation of ground-level ozone and particulate matter, exacerbating air quality issues and leading to respiratory problems, asthma attacks, and cardiovascular diseases.
- Additionally, NOx plays a role in the formation of acid rain, which can damage ecosystems, soil, and infrastructure.

- According to **Indian Nitrogen Assessment:**
  - Agricultural soils contributed to over 70% of N_2O emissions from India in 2010.
  - Cattle account for 80% of the ammonia production.
  - The poultry industry recorded an excretion of reactive nitrogen compounds of 0.415 tonnes in 2016.

Sulphur Dioxide (SO_2)

- Sulphur dioxide is a colorless gas with a pungent odor, primarily emitted from the combustion of fossil fuels containing sulphur, such as coal and oil.
- Industrial processes, smelter sites, power plants, and transportation are major sources of SO_2 emissions.
- SO_2 can react with other compounds in the atmosphere to form sulphate particles, contributing to the formation of fine particulate matter and secondary aerosols.
- Exposure to SO_2 can irritate the respiratory system, exacerbate asthma symptoms, and cause respiratory diseases such as bronchitis and pneumonia.

Carbon Monoxide (CO)

- Carbon monoxide is a colorless, odorless gas produced by the incomplete combustion of fossil fuels, biomass, and organic matter.
- Vehicle emissions, industrial processes, and residential heating systems are primary sources of CO emissions.
- CO binds to hemoglobin in the bloodstream, reducing the blood's ability to carry oxygen, leading to symptoms such as headaches, dizziness, nausea, and, at high concentrations, can be fatal.
- Chronic exposure to low levels of CO can have long-term health effects, including cardiovascular problems and neurological disorders.

Volatile Organic Compounds (VOCs)

- Volatile organic compounds are a diverse group of organic chemicals that evaporate easily into the air.
- Sources of VOCs include vehicle emissions, industrial processes, solvents, paints, cleaning products, and vegetation.
- VOCs contribute to the formation of ground-level ozone and secondary aerosols, as well as indoor air pollution.
- Prolonged exposure to VOCs can cause eye, nose, and throat irritation, headaches, nausea, and damage to the liver, kidneys, and central nervous system.

Ozone (O_3)

- Ground-level ozone is a secondary pollutant formed by the reaction of NOx and VOCs in the presence of sunlight.
- Ozone is a major component of smog and is harmful to human health, particularly to the respiratory system.
- It can cause shortness of breath, chest pain, coughing, throat irritation, and aggravate existing respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD).
- Ozone exposure is also linked to cardiovascular problems, inflammation, and premature death.

Difference between Air Pollutants and Greenhouse Gases

Aspect	Air Pollutants	Greenhouse Gases (GHGs)
Definition	Substances released into the atmosphere with harmful effects on health, ecosystems, or the environment.	Gases in the Earth's atmosphere that trap heat and contribute to global warming and climate change.
Chemical Properties	Can be solid particles, liquid droplets, or gases. Include both primary and secondary pollutants.	Typically gases with three or more atoms in their molecules, allowing them to absorb and emit infrared radiation.
Sources	Natural sources (e.g., wildfires, volcanic eruptions) and human activities (e.g., transportation, industry).	Primarily generated by human activities such as burning fossil fuels, deforestation, agriculture, and industry.
Examples	Particulate matter (PM10, PM2.5), nitrogen oxides (NOx), sulphur dioxide (SO_2), carbon monoxide (CO), volatile organic compounds (VOCs), lead (Pb).	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6).
Effects	Respiratory problems, cardiovascular diseases, acid rain, smog formation, damage to vegetation and ecosystems. Indirectly contribute to climate change.	Contribute to the greenhouse effect, leading to global warming, rising temperatures, melting ice caps, sea level rise, altered weather patterns, and climate-related impacts.

Air Pollution Status

Global Air Pollution

- Globally, air pollution contributed to **11.65% of deaths in 2023.**

Top 10 most polluted cities in the world (IQ Air's World Air Quality Index Report 2023)

S. No.	City Name	Country	AQI
1	Dammam	Saudi Arabia	514
2	Delhi	India	483
3	Lahore	Pakistan	371
4	Kolkata	India	206
5	Dhaka	Bangladesh	189
6	Karachi	Pakistan	162
7	Mumbai	India	162
8	Shenyang	China	159
9	Hangzhou	China	159
10	Kuwait City	Kuwait	155

Air Pollution in India

- Air Pollution levels in India was around **53.3** µg/m³ **in as per 2022 World Air Quality Report.**

  *{**Global average** of air pollution in 2023 was **21 µg/m³**; A concentration of **1 µg/m³** means that **one cubic metre of air contains one microgram (10^{-6} grams) of pollutant.}*
- Majority of India's population live in areas where the **annual average particulate pollution** level exceeds the WHO guideline.
- **67.4 percent** of the population live in areas that exceed the country's own national air quality standard of **40 µg/m³**
- Measured in terms of life expectancy, **particulate pollution** is the greatest threat to human health in India, taking **5.3 years** off the life of the average Indian.
  - In contrast, **cardiovascular diseases** reduce the average Indian's life expectancy by about **4.5 years**, while child and maternal malnutrition reduce life expectancy by 1.8 years.

Causes of Air Pollution

Natural Causes

- **Volcanic Eruptions:** Volcanic eruptions release sulphur dioxide (SO_2), carbon dioxide (CO_2), ash, Hydrogen Sulfides, Hydrogen Halides, Hydro Chloric Acid, Mercury vapours and other pollutants into the atmosphere, contributing to air pollution.
- **Wildfires:** Forest fires and vegetation burning release large amounts of particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOCs), and other pollutants into the air, causing air pollution.
- **Biogenic Sources:** Natural sources such as pollen, spores, and emissions from plants and trees can contribute to air pollution, especially during periods of high biological activity.
- **Dust Storms:** Natural events such as dust storms and sandstorms can transport large amounts of dust and particulate matter into the atmosphere, leading to localized air pollution.
- **Oceanic emissions:** Marine organisms and processes like phytoplankton blooms can release dimethyl sulfide (DMS) and other gases into the atmosphere, which can contribute to aerosol formation and air pollution.
- **Radon emissions:** Radon, a naturally occurring radioactive gas, can seep into buildings from the ground and accumulate indoors, contributing to indoor air pollution.
- **Dust and particulate matter from natural landscapes:** Dust and particulate matter are constantly generated by natural processes such as wind erosion, sea spray, and geological activities like landslides. These particles can become suspended in the air and contribute to air pollution.

Anthropogenic Causes

- **Fossil Fuel:** When fossil fuels are burned, they release various pollutants into the atmosphere, including carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NOx), particulate matter (PM), and volatile organic compounds (VOCs).
  - These pollutants contribute to the formation of smog, acid rain, and ground-level ozone, leading to respiratory problems, cardiovascular diseases, and other health issues.
- **Industrial Activities:** Emissions from industries, including power plants, smelter sites, factories, refineries, and manufacturing facilities, release pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NOx), particulate matter (PM), CO, CO_2, heavy metals, and volatile organic compounds (VOCs) into the air.
  - **Example: Furnace oil,** also known as fuel oil or residual fuel oil, is a dark, viscous liquid derived from crude oil through a refining process. Furnace oil is valued for its high energy content and relatively low cost compared to other fuels, making it a popular choice in sectors such as manufacturing, power generation, and shipping. However, its combustion releases pollutants such as sulphur dioxide and nitrogen oxides.
- **Vehicle Emissions:** Combustion engines in vehicles, including cars, trucks, buses, and airplanes, emit pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC), benzene, and particulate matter (PM), contributing to air pollution, especially in urban areas.

- **Agricultural Activities:** Agricultural practices such as burning of crop residues, use of fertilizers and pesticides, and livestock farming release pollutants such as ammonia (NH_3), methane (CH_4), Carbon monoxide, Ozone, Sulphur dioxide and nitrous oxide (N_2O) into the air, contributing to air pollution.
  - **Example:** Stubble burning is the practice of intentionally setting fire to the straw stubble(also called 'Parali'), that remains after grains, such as rice and wheat, have been harvested.
    - Stubble burning in late October-November in the states of Punjab,Haryana and western UP is the leading cause of air pollution and winter smog in Delhi.
- **Urbanization and Construction:** Urbanization, construction activities, and land development release dust, particulate matter, and pollutants such as nitrogen oxides (NOx) and volatile organic compounds (VOCs) into the air, leading to urban air pollution.
- **Waste Burning:** Open burning of waste, including municipal solid waste, agricultural residues, and biomass, releases pollutants such as carbon monoxide (CO), particulate matter (PM), benzene, and toxic chemicals into the air, contributing to air pollution.
- **Tobacco smoke:** More than 7,000 chemicals have been identified in second hand tobacco smoke. At least 69 of these chemicals are known to cause cancer, including arsenic, benzene, beryllium, chromium, and formaldehyde.
- **Indoor air pollution** which is even more harmful is caused by poor ventilation, use of biomass like cow dung and wood for cooking and heating, furnishings, cleaning etc.

Harmful Effects of Air Pollution

Effects on Health

- **Respiratory and Cardiovascular Health Impacts:** Air pollution can cause or exacerbate respiratory conditions such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD).
  - **Fine particulate matter** (PM2.5) and ozone (O_3) can penetrate deep into the lungs, causing inflammation, respiratory symptoms, and decreased lung function.
  - Air pollution is also linked to cardiovascular problems such as heart attacks, strokes, and high blood pressure.
- **Increased Risk of Cancer:** Long-term exposure to air pollution, particularly to pollutants such as benzene, formaldehyde, and polycyclic aromatic hydrocarbons (PAHs), is associated with an increased risk of developing lung cancer, bladder cancer, and other types of cancer.
- **Neurological and Cognitive Effects:** Air pollution has been linked to neurological and cognitive effects, including impaired cognitive development in children, decreased cognitive function in adults, and an increased risk of neurodegenerative diseases such as Alzheimer's and Parkinson's disease.
  - **Example:** According to recent studies, air pollution in cities like New Delhi has been linked to children's cognitive decline, Alzheimer's and even death.
- Reproductive and Developmental Effects: Exposure to air pollution during pregnancy is associated with adverse pregnancy outcomes such as low birth weight, preterm birth, and birth defects.
  - Air pollutants can also cross the placenta and affect fetal development, leading to long-term health problems in children.

Effects on the Environment

- Ecological degradation: Air pollution can harm ecosystems and wildlife by damaging vegetation, reducing crop yields, and disrupting ecological processes.
  - Acid rain, caused by sulphur dioxide (SO_2) and nitrogen oxides (NOx) emissions, can acidify soil and water bodies, leading to the loss of biodiversity and damage to aquatic ecosystems and damage historical monuments. ex Taj Mahal discolouration due to acid rain.
- Climate Change: Some air pollutants, such as carbon dioxide (CO_2), methane (CH_4), and black carbon (soot), contribute to climate change by trapping heat in the atmosphere and altering global climate patterns.
  - This can lead to a range of environmental impacts, including rising temperatures, melting ice caps, and more frequent and severe weather events.

South-East Asian Haze 2023

- Haze is traditionally an atmospheric phenomenon in which **dust, smoke, and other dry particulates** suspended in air obscure visibility and the clarity of the sky.
- **South East Asian Haze** refers to a transboundary haze across parts of South East Asia due to hazardous increase in airborne particulate matter due to **burning biomass.**
- **Indonesia** and **Malaysia's peatland fires** contribute to the majority of transboundary haze, most notably due to **slash-and-burn techniques** in **Sumatra** and the **Kalimantan** region of Borneo Island.

{Peatlands are terrestrial wetland ecosystems in which waterlogged conditions prevent plant material from fully decomposing}

Measures to Control Air Pollution

Global Initiatives

- **Gothenburg Protocol:**
  - The Gothenburg Protocol is an international agreement under the United Nations Economic Commission for Europe (UNECE), aiming to reduce air pollution and its transboundary effects in Europe.

- Adopted in 1999 and amended in 2012, the protocol sets emission reduction targets for key air pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NOx), volatile organic compounds (VOCs), and ammonia (NH_3).
- It establishes national emission ceilings for these pollutants and requires parties to implement measures to meet these targets, thus improving air quality and protecting ecosystems.

❑ **Climate and Clean Air Coalition (CCAC):**

- The Climate and Clean Air Coalition is a global partnership of governments, intergovernmental organizations, businesses, scientific institutions, and civil society organizations.
- Launched in 2012, the coalition aims to reduce short-lived climate pollutants (SLCPs) such as methane, black carbon, and hydrofluorocarbons (HFCs), which contribute to both air pollution and climate change.
- By promoting policies and technologies to reduce SLCP emissions, the CCAC seeks to improve public health, protect the environment, and slow down global warming in the near term.

❑ **Global Methane Pledge:**

- This voluntary agreement aims to collectively reduce global methane emissions by 30% by 2030. Methane is a potent greenhouse gas and air pollutant, so reducing it helps tackle both climate change and air quality issues.

❑ **WHO Air Quality Guidelines:**

- The World Health Organization (WHO) establishes air quality guidelines to provide scientifically based recommendations for air quality standards worldwide.
- These guidelines set concentration levels for key air pollutants, including particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO), to protect public health.
- WHO periodically reviews and updates these guidelines based on the latest scientific evidence, aiming to ensure that they reflect the best available knowledge on the health effects of air pollution.

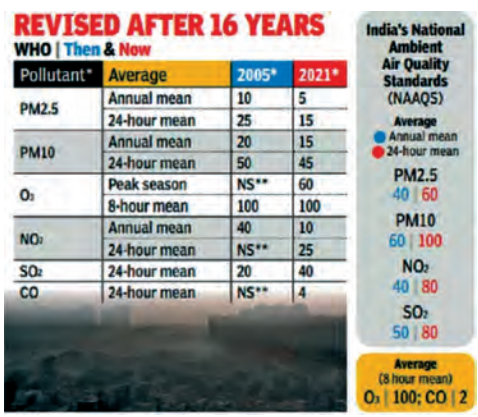

REVISED AFTER 16 YEARS
WHO | Then & Now
Pollutant* | Average | 2005* | 2021*
PM2.5 | Annual mean | 10 | 5
24-hour mean | 25 | 15
PM10 | Annual mean | 20 | 15
24-hour mean | 50 | 45
O3 | Peak season | NS** | 60
8-hour mean | 100 | 100
NO2 | Annual mean | 40 | 10
24-hour mean | NS** | 25
SO2 | 24-hour mean | 20 | 40
CO | 24-hour mean | NS** | 4
India's National Ambient Air Quality Standards (NAAQS)
Average
Annual mean
24-hour mean
PM2.5
40 | 60
PM10
60 | 100
NO2
40 | 80
SO2
50 | 80
Average
(8 hour mean)
O3 | 100; CO | 2

Fig. 9.1: WHO Air Quality Guidelines

Significance

❑ **Expanded Pollutant Coverage:** The revised AQGs provide guidelines for six pollutants: particulate matter (PM2.5 and PM10), ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and carbon monoxide (CO). This broader coverage reflects a more comprehensive understanding of air pollution's health impacts.

❑ **Stricter Limits:** The guidelines introduce stricter limits for the recommended levels of air pollutants. For example, the annual average for PM2.5 should not exceed 5 micrograms per cubic meter, while the 24-hour average should not exceed 15 micrograms per cubic meter. Similarly, limits are set for other pollutants, emphasizing the need for improved air quality.

❑ **Changes from the 2005 Update:**

- **Time Gap:** The previous update of the AQGs was released in 2005, making the recent revision the first in nearly two decades. This time gap underscores the importance of addressing emerging scientific evidence, health risks, and changing global air pollution patterns.
- **Inclusion of New Pollutants:** The 2021 revision includes guidelines for additional pollutants, such as PM2.5 and PM10. These fine particulate matters are known to have severe health effects and were not covered in the 2005 update.

National Initiatives

The Air (Prevention and Control of Pollution) Act, 1981

❑ The Air (Prevention and Control of Pollution) Act, 1981 is a legislation enacted by the Government of India to address the growing concerns regarding air pollution and its adverse effects on human health and the environment.

❑ **Key features of the Act:**

- **Objective:** The primary objective of the Air Act is to prevent and control air pollution by regulating emissions of pollutants from industrial processes, automobiles, and other sources, and to establish authorities for the implementation and enforcement of air quality standards.
- **Regulatory Framework:** The Act provides for the establishment of State Pollution Control Boards (SPCBs) and the Central Pollution Control Board (CPCB), which are responsible for implementing pollution control measures, monitoring air quality, and enforcing compliance with air pollution standards.
- **Pollution Control Measures:** The Air Act empowers the pollution control boards to prescribe standards for the emission of pollutants from industries, vehicles, and other sources, and to take measures for the prevention, control, and abatement of air pollution.

National Clean Air Programme

- The Ministry of Environment, Forest and Climate Change (MoEFCC) launched the National Clean Air Programme (NCAP) in January, 2019 with the aim of improving air quality in 131 cities (non-attainment cities and Million Plus Cities) in 24 States/UTs by engaging all stakeholders.
- The programme envisages to achieve reductions up to 40% or achievement of National Ambient Air Quality Standards for Particulate Matter10 (PM 10) concentrations by 2025-26.
- 82 cities under NCAP have been provided an annual target of 3-15% reduction of PM10 levels to achieve an overall reduction of air quality up to 40% PM10 levels, and 49 cities under the XVth Finance Commission air quality grant, have been given an annual target of 15% reduction in annual average Particulate Matter10 (PM10) concentrations and improvement of good air quality days (Air Quality Index less than 200)
- **Non-attainment cities**
  - The CPCB has identified a list of polluted cities in which the prescribed NAAQS are violated, called non-attainment cities.
    - These cities have been identified based on the ambient air quality data obtained (2011–2015) under NAMP.
  - Based on WHO's fourth Ambient Air Quality Database there are 102 non-attainment cities in India.
    - PM10 has been found to be exceeding in 94 cities consecutively for five years and NO_2 is exceeding the limits in five cities.
    - PM2.5 data since 2015 indicates 16 cities as non-attainment cities.

Graded Response Action Plan(GRAP)

- GRAP, or Graded Response Action Plan, is an emergency response mechanism implemented in the Delhi-National Capital Region (NCR) to combat air pollution. It outlines a series of measures that are progressively triggered based on the severity of air quality as determined by the Air Quality Index (AQI).
- **Objectives:**
  - Reduce air pollution during periods of high PM2.5 and PM10 concentrations.
  - Protect public health from the harmful effects of air pollution.
  - Minimize inconvenience to citizens by implementing proportionate measures based on air quality severity.
- GRAP defines four stages based on AQI levels:
  - **Stage I - Poor (AQI 201-300):** Advisories issued, construction dust control measures implemented.
  - **Stage II - Very Poor (AQI 301-400):** Enhanced dust control, restrictions on brick kilns and hot mix plants.
  - **Stage III - Severe (AQI 401-450):** Ban on coal-based industries, stricter vehicle emission norms.
  - **Stage IV - Severe+ (AQI above 450):** Emergency measures like school closures, odd-even vehicle rationing.

NAMP (National Air Quality Monitoring Programme)

- NAMP is a nationwide initiative launched by the Central Pollution Control Board (CPCB) to monitor and assess air quality in various cities and industrial areas across India.
- It aims to establish a network of air quality monitoring stations equipped with advanced instruments to measure ambient air quality parameters.
- NAMP facilitates the collection of data on air pollutants such as particulate matter (PM10 and PM2.5), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and ozone (O_3), enabling regulatory authorities to formulate effective pollution control policies.

WAYU (Wind Augmentation PurifYing Unit)

- WAYU is an indigenous air purification technology developed by the Council of Scientific and Industrial Research (CSIR) in collaboration with a private firm.
- It is a compact, high-efficiency air purifier designed to reduce particulate matter (PM2.5 and PM10) and harmful gases from ambient air in urban areas.
- WAYU units are deployed at various locations, such as traffic intersections, markets, and public spaces to improve local air quality and mitigate the adverse health effects of air pollution.

Norms for Thermal Power Plants (TPPs)

- All Thermal Power Plants required to comply with Emission Norms notified by MOEFCC and directions given by the Central Pollution Control Board (CPCB)
- Emissions Norms: Sulphur Dioxide (SO2): Installation of Flue gas desulphurization to minimize SO2 emissions and comply with the emission standards.
  - 22 Thermal Power Plants having a total capacity of 9280 MW have installed Flue Gas Desulphurization.
  - **Nitrogen Oxides (NOx):** Stringent norms in place for new plants, existing plants have specific phased timelines for compliance.
  - **Particulate Matter (PM):** Limits set for PM emissions based on plant size and fuel type.
  - **Mercury:** Specific emission limits are prescribed for new plants, older plants require the installation of control measures.

Flue Gas Desulphurization

Flue Gas Desulphurization (FGD) is a technology used to remove sulphur dioxide (SO_2) from the exhaust flue gases of industrial processes, particularly those associated with power generation using fossil fuels such as coal or oil.

Environment Pollution (Prevention and Control) Authority (EPCA)

- EPCA was a statutory body constituted by the Government of India under the Environment (Protection) Act, 1986, to address environmental issues, particularly air pollution, in the National Capital Region (NCR) and other critically polluted areas.
- It comprised of experts, officials, and representatives from government agencies, civil society organizations, and the public.
- EPCA was responsible for implementing various measures to combat air pollution, including enforcing pollution control regulations, monitoring compliance, and coordinating with relevant authorities to ensure effective implementation of pollution control measures. It was dissolved and replaced by Commission for Air Quality Management.

Commission for Air Quality Management (CAQM)

- The Commission for Air Quality Management in the National Capital Region and Adjoining Areas Ordinance, 2021 was promulgated on April 13, 2021 which was later replaced by the act of parliament.
- Adjoining areas have been defined as areas in the states of Haryana, Punjab, Rajasthan, and Uttar Pradesh adjoining the NCR where any source of pollution may cause adverse impacts on air quality in the NCR.
- The Ordinance also dissolves the Environment Pollution Prevention and Control Authority established in the NCR in 1998.
- Functions of the Commission
  - (i) Co-ordinating actions taken under the Ordinance by concerned state governments (Delhi, Haryana, Punjab, Rajasthan, and Uttar Pradesh)
  - (ii) Planning and executing plans to prevent and control air pollution in the NCR
  - (iii) Providing a framework for the identification of air pollutants
  - (iv) Conducting research and development through networking with technical institutions

National Air Quality Index(NAQI)

- The National Air Quality Index is a tool developed by CPCB to asses the air quality and extent of air pollution in a region.
- It is based on the vision - 'One Number- One Colour-One Description' for the common man to judge the air quality within their vicinity.
- NAQI monitors eight pollutants - Particulate Matter: PM10, PM2.5, Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Carbon Monoxide (CO), Ozone (O_3), Ammonia (NH_3), and Lead (Pb).
- These pollutants have been prescribed short-term (upto 24-hours) standards called National Ambient Air Quality Standards.
- There are six AQI categories, namely Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe. Each of these categories is decided based on the ambient concentration values of air pollutants and their likely health impacts (known as health breakpoints).

Comprehensive Environmental Pollution Index(CEPI)

- The Comprehensive Environmental Pollution Index is a tool developed by the Central Pollution Control Board(CPCB) to assess the quality of the environment.
- It gives a rational no., which ranges between 0-100 to indicate the overall quality of the environment by following an algorithm of pollution sources, pathways and receptors across air, surface water and land.

Swachh Vayu Survekshan

- "Swachh Vayu Survekshan" is an initiative by MoEF&CC to rank cities on the basis of implementation of activities approved under the city action plan and air quality in 131 NCAP cities.
- Cities are designated as 'non-attainment' areas when, over a five-year period, they consistently fail to meet the National Ambient Air Quality Standards (NAAQS) for PM10 or Nitrogen Dioxide (NO_2).
- Assessment Mechanism
  - Assessment is done based on the submission of self - assessment report along with supporting documents by ULBs.
    - All 131 cities covered under NCAP are assessed based on ranking framework submitted by Cities/ ULBs on the PRANA portal (Dashboard to capture progress of NCAP programme).
  - The reports and documents are further vetted by the respective Air Quality Monitoring Committee (AQMC), chaired by the Principal Secretary Environment and further examined and evaluated by the CPCB for ranking, on the basis of assessment framework given in MoEF&CC guideline.
- Performance **(Population - CENSUS 2011)**
  - Under the first category (more than 10 lakh population) Indore ranked first followed by Agra and Thane.
  - In the second category (between 3-10 lakhs population), Amravati secured the first rank followed by Moradabad and Guntur.
  - Similarly, for the third category (less than 3 lakhs population) Parwanoo (Himachal Pradesh) secured first rank followed by Kala Amb (Himachal Pradesh) and Angul (Odisha).

SAFAR (System of Air Quality and Weather Forecasting) Portal

- SAFAR is a comprehensive air quality monitoring and forecasting system developed by the Ministry of Earth Sciences, Government of India.
- It provides real-time information on air quality, weather parameters, and atmospheric pollutants in major cities across India.
- The portal helps policymakers, researchers, and the public make informed decisions regarding health protection and pollution control measures.

National Ambient Air Quality Standards (NAAQS)

- National Ambient Air Quality Standards (NAAQS) in India are regulatory limits set by the Central Pollution Control Board (CPCB) to define the maximum permissible concentrations of various air pollutants in ambient outdoor air. These standards aim to protect public health from the harmful effects of air pollution.
- NAAQS in India currently regulates the following 6 criteria pollutants:
  - **Particulate Matter (PM):** PM2.5 (fine particles) and PM10 (coarse particles)
  - Sulfur dioxide (SO_2); Nitrogen dioxide (NO_2); Ozone (O_3); Lead (Pb); Ammonia (NH_3).
- **Types of NAAQS:**
  - **Annual standards:** Set the permissible average concentration of a pollutant over a year.
  - **24-hourly standards:** Set the permissible average concentration of a pollutant over a 24-hour period.
- **Significance:**
  - NAAQS serves as a benchmark for evaluating air quality in India and guides policy decisions related to air pollution control measures.
  - State Pollution Control Boards (SPCBs) are responsible for monitoring air quality and implementing action plans to achieve and maintain NAAQS within their respective states.
- **Challenges:**
  - **Non-attainment of standards:** Many Indian cities consistently exceed NAAQS, particularly for PM2.5, posing significant health risks.
  - **Enforcement and implementation:** Effective enforcement of regulations and implementation of control measures remain challenging.
  - **Need for revision:** Regular review and revision of NAAQS based on scientific advancements and an evolving understanding of health impacts is crucial.

Overall, NAAQS in India play a vital role in addressing air pollution concerns and protecting public health. However, addressing existing challenges and strengthening implementation efforts are essential for achieving cleaner air and safeguarding the well-being of citizens.

H-CNG as an Automotive Fuel

The Ministry of Petroleum & Natural Gas issued a draft notification, following a NITI Aayog proposal, for H-CNG as an automotive fuel.

- H-CNG is a blend of hydrogen and CNG, the ideal hydrogen concentration being 18%.
- Compared to conventional CNG, use of H-CNG can reduce emissions of carbon monoxide up to 70%, besides enabling up to 5% savings in fuel.

Assessment of Air Pollution Control Measures

Performance Analysis Report of NCAP by CREA

The Centre for Research on Energy and Clean Air (CREA) released a report analyzing the four-year performance of the National Clean Air Programme (NCAP) in India. Here's a summary of their findings:

Positive Aspects

- **Air quality improvement:** 49 out of 131 cities showed improved air quality compared to the previous year.
- **Framework established:** Committees and frameworks for implementing, monitoring, and reviewing NCAP actions have been formulated.

Areas for Improvement

- **Target achievement:** Only 38 cities achieved their annual pollution reduction targets.
- **Slow progress:** Only 37 out of 131 cities have completed source apportionment studies, crucial for identifying pollution sources.
- **Limited transparency:** Information sharing on the functioning and effectiveness of NCAP measures at the state level remains opaque.
- **Incomplete monitoring network:** The rural air quality monitoring network is limited, and efforts to expand it haven't been fully realized.

Recommendations by CREA

- **Enhanced coordination and monitoring:** Strengthen collaboration between various stakeholders and improve air quality monitoring, particularly in rural areas.
- **Effective utilization of funds:** Ensure allocated funds are used efficiently for implementing NCAP actions.
- **Reassessing non-attainment cities:** Reevaluate the list of non-attainment cities based on recent air quality data to ensure all polluted areas are included in the program.
- **Increased transparency:** Improve public access to information on NCAP implementation and progress.

Overall, the analysis suggests that while there has been some progress in improving air quality, the NCAP's implementation needs significant improvement to achieve its ambitious goals.

Way Forward

Regulations and Standards

- Implementation of stringent air quality standards and regulations to limit emissions of pollutants from industrial facilities, power plants, vehicles, and other sources.
- Example: India has established the National Ambient Air Quality Standards (NAAQS) to regulate the concentration of pollutants in the ambient air.

Transition to Clean Energy

- Promotion of renewable energy sources such as solar, wind, and hydropower to reduce reliance on fossil fuels and decrease emissions of greenhouse gases and air pollutants.
- **Example:** PM Surya Ghar: Muft Bijli Yojana rooftop solar scheme with an investment of over ₹75,000 crore helps in the clean energy transition through decentralized solar power generation.

Vehicle Emission Controls

- Implementation of vehicle emission standards and regulations to reduce pollutants emitted from automobiles, including particulate matter, nitrogen oxides, sulphur dioxide, and volatile organic compounds.
- Example: Implementation of stricter emission norms for vehicles, such as Bharat Stage VI norms (equivalent to Euro VI standards), has led to the adoption of cleaner technologies and fuels to reduce pollutants from automobiles.

Bharat Stage Norm

- Bharat stage emission standards are emission standards instituted by the Government of India to regulate the output of air pollutants from compression ignition engines and Spark-ignition engines equipment, including motor vehicles.
- India has adopted Bharat Stage (BS) Emission Standards since 2000, modelled on EU norms.
- In April 2020, India leapfrogged from BS-IV to the implementation of BS-VI, with current standards similar to Euro-6/VI norms.
- The BS standards regulate tailpipe emissions of air pollutants including particulate matter, SOx and NOx as well as carbon monoxide, hydrocarbons and methane. They have been developed for all vehicle categories and apply to vehicles manufactured since April 2020.

Industrial Pollution Control

- Adoption of pollution prevention and control measures in industrial processes to minimize emissions of pollutants, including installing pollution control equipment, optimizing production processes, and implementing cleaner production technologies.
- **Example:** Industries are required to install pollution control equipment such as electrostatic precipitators, scrubbers, and catalytic converters to minimize emissions.

Transportation Planning and Management

- Implementation of sustainable transportation strategies, such as promoting public transit, biking, walking, and ridesharing, to reduce vehicle congestion, emissions, and air pollution in urban areas.
- **Example:** The FAME India Scheme, aimed at promoting electric vehicles (EVs) in the country, has taken significant strides to incentivize the adoption of EVs and expand the electric mobility infrastructure.

  {**FAME India Scheme** is a part of the **National Electric Mobility Mission Plan**}

Waste Management Practices

- Implementation of proper waste management practices, including recycling, composting, and waste-to-energy technologies, to reduce emissions of air pollutants from landfills and incineration facilities.
- **Example:** Initiatives like the National Clean Air Programme (NCAP) include provisions for addressing waste burning and open waste dumping, which contribute to air pollution emissions.

Awareness and Education

- Public awareness campaigns, education programs, and community engagement initiatives to raise awareness about the causes, effects, and solutions to air pollution.
- **Example:** Public awareness campaigns, such as the "Clean Air for Delhi" campaign, raise awareness about the health impacts of air pollution and encourage citizen participation in air quality improvement efforts.

OTHER ISSUES RELATED TO AIR POLLUTION

Stubble Burning

- Stubble burning is the practice of intentionally setting fire to the leftover straw stubble(also called 'parali'), after harvesting grains like rice and wheat.
- This practice is prevalent in parts of North India, particularly in Punjab, Haryana, and Uttar Pradesh.

Stubble burning and Delhi air pollution

- **Stubble burning** in Punjab, Haryana, and Uttar Pradesh in north India has been cited as a **major cause of air pollution in Delhi since 1980.**
- Stubble burning in Punjab and Haryana has typically accounted for **30% to 40%** of Delhi's October-November pollution, according to government air-quality monitoring agency **SAFAR**.
  - Consequently, the government is considering the implementation of the 1400 km long and 5 km wide **Great Green Wall of Aravalli.**

Reasons for Stubble Burning

- **Quick and cheap method:** Farmers often resort to stubble burning as a quick and inexpensive way to clear their fields for the next sowing season.
- **Limited alternatives:** Lack of readily available and affordable alternatives for managing crop residue contributes to the persistence of this practice.
- **High costs of alternatives:** The average cost of machines like Happy Seeder is very high and hence expensive especially for small and marginal farmers in India.
  - The average waiting time to rent a machine is about two weeks, resulting in inordinate delays.
- **Inadequate Government Support:** Insufficient government support and incentives for promoting alternative crop residue management practices contribute to the continuation of stubble burning.
  - Limited access to subsidies, technical assistance, and infrastructure for implementing alternative methods hinders adoption by farmers.

Consequences of Stubble Burning

- **Air Pollution:**
  - Stubble burning releases harmful pollutants such as particulate matter (PM2.5 and PM10), carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOCs) into the atmosphere, leading to severe air pollution.
  - Worsens air quality in the National Capital Region (NCR) and surrounding areas, contributing to smog, haze, and respiratory issues.
- **Health Impacts:**
  - Exposure to smoke from stubble burning increases the risk of respiratory diseases such as asthma, bronchitis, and lung infections.
  - Causes eye irritation, coughing, throat irritation, and other health problems among residents, especially vulnerable populations such as children, the elderly, and individuals with pre-existing respiratory conditions.
- **Environmental Degradation:**
  - Contributes to regional haze, reducing visibility and impacting ecosystems, biodiversity, and wildlife habitats.
  - Degrades soil quality by burning organic matter and depleting soil nutrients, affecting agricultural productivity and soil fertility.
- **Climate Change:**
  - Releases greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4) into the atmosphere, contributing to global warming and climate change.
  - Accelerates the melting of glaciers, changes in rainfall patterns, and other adverse impacts on weather and climate systems.
- **Biodiversity Loss:**
  - Air and water pollution from stubble burning can have detrimental effects on biodiversity, leading to habitat degradation and loss of species diversity.
  - Pollutants released into the environment can harm plants, animals, and microorganisms, disrupting ecological processes and the food chains.
  - Loss of habitat and food sources due to pollution can threaten the survival of wildlife species, including birds, mammals, amphibians, and aquatic organisms.

Measures taken to Mitigate Stubble Burning

- **Imposing penalties:** Some states have implemented stricter penalties for stubble burning, although effective enforcement remains a challenge.
- **Monitoring and surveillance:** Utilizing satellite imagery and ground-level monitoring systems can help identify instances of burning and enable targeted interventions.
- **Promoting innovation:** Encouraging startups and private companies to develop innovative solutions for stubble management can accelerate progress in this area.
- **Subsidies and financial assistance:** Schemes like PM-KUSUM and the Biomass Utilization Scheme provide subsidies for purchasing machinery like Happy Seeders, mulchers, and super straw choppers, which help manage crop residue without burning.
- **Market development for paddy straw:** Initiatives like Biogas Mission and Pashu Dhan Vikas Yojana promote the use of paddy straw for biogas production and animal bedding, creating additional income opportunities for farmers.
- **Compensation schemes:** Some states like Punjab and Haryana have implemented pilot schemes offering financial compensation to farmers who adopt alternative residue management practices.

Challenges

- **Financial Constraints:** Small and marginal farmers may lack the financial resources to invest in machinery and equipment for alternative crop residue management. Subsidies and financial incentives are needed to make sustainable practices more accessible and affordable.

- **Infrastructure and Technology:** Inadequate infrastructure and limited availability of machinery for crop residue management pose challenges to adopting alternative practices. Investment in infrastructure and technology is essential to facilitate the transition away from stubble burning.
- **Behavioral Change:** Stubborn adherence to traditional practices and cultural norms surrounding stubble burning may hinder efforts to change behavior. Promoting behavioral change through social and community engagement initiatives is necessary.
- **Policy Implementation and Enforcement:** Inconsistent enforcement of regulations and lack of penalties for stubble burning make it difficult to deter farmers from engaging in this practice. Strengthening policy implementation and enforcement mechanisms is crucial.
- **Coordination and Collaboration:** Effective coordination and collaboration among government agencies, agricultural organizations, research institutions, and farmers are essential to implement comprehensive solutions to stubble burning. Lack of coordination can lead to fragmented efforts and limited impact.

Way Forward

- **Government policies:** Providing market avenues for crop residue and legal backing against polluting practices could end farm fires.
  - Supreme Court formed Madan B. Lokur committee to monitor and take steps to prevent stubble burning in the states of Punjab, Haryana & Uttar Pradesh
- **Education and Awareness:**
  - **Example:** The Punjab Remote Sensing Centre (PRSC) has developed an app called "PAANI" to provide real-time information on crop residue burning incidents to farmers.
  - This initiative educates farmers about the harmful effects of stubble burning and encourages them to adopt alternative practices.
- **Financial Support:**
  - **Example:** The Government of India's "Sub-Mission on Agricultural Mechanization" provides financial assistance to farmers for the purchase or hiring of machinery such as Happy Seeders and Mulchers, which help in managing crop residue without burning.
- **Infrastructure Development:**
  - **Example:** The Punjab government has set up Biomass Power Plants to utilize crop residue for electricity generation. This initiative not only helps in managing crop residue effectively but also provides additional income opportunities for farmers.
- **Behavioral Change Initiatives:**
  - **Example:** NGOs like the Climate Reality Project India conduct awareness campaigns and workshops in rural areas to educate farmers about the environmental and health impacts of stubble burning, promoting behavioral change through community engagement.
- **Market Development:**
  - **Example:** The Punjab government incentivizes the establishment of bioenergy projects and industries for producing biofuels and biochar from crop residue. This creates a market for residue-based products, encouraging farmers to adopt residue management practices.
- **Technocentric Solutions:**
  - **Examples:** The "Pusa Decomposer" developed by the Indian Agricultural Research Institute (IARI) is a microbial solution that helps in decomposing crop residue quickly, allowing farmers to manage residue effectively within the short window between harvest and sowing.
  - **Pelletisation & Torrefaction:** MoEFCC released Central Pollution Control Board (CPCB) guidelines for grant of one-time financial support for promoting establishment of paddy straw based pelletisation and torrefaction plants.
    - **Pelletisation:** Involves shredding, drying, grinding and pellet making.
    - **Torrefaction:** Thermal degradation of organic biomass.
    - **Major difference between pelletisation and Torrefaction:** Presence of a torrefaction reactor.
    - **Use of Paddy straw made into pellets or torrefied:** Can be mixed along with coal in TPPS to save coal and reduce carbon emissions.

Ozone Depletion

- Ozone depletion refers to the thinning of the ozone layer in the Earth's stratosphere, particularly over the polar regions.
- It is primarily caused by human-made chemicals called chlorofluorocarbons (CFCs), halons, and other ozone-depleting substances (ODS) released into the atmosphere.
- The depletion of the ozone layer allows more ultraviolet (UV) radiation from the sun to reach the Earth's surface, leading to increased risks of skin cancer, cataracts, and damage to ecosystems.
  - The Montreal Protocol, an international treaty signed in 1987, aims to phase out the production and use of ozone-depleting substances to protect the ozone layer.

Acid Rain

- Acid rain is rainfall or any other form of precipitation that contains acidic components, such as sulphuric acid and nitric acid, resulting from the atmospheric deposition of pollutants.
- It is primarily caused by emissions of sulphur dioxide (SO_2) and nitrogen oxides (NOx) from industrial processes, vehicle exhaust, and fossil fuel combustion.

- Acid rain can have harmful effects on soil, water bodies, vegetation, and infrastructure, leading to soil acidification, water pollution, forest decline, and the corrosion of buildings and monuments.
- Efforts to mitigate acid rain include reducing emissions of sulfur and nitrogen oxides, implementing clean air regulations, and promoting cleaner technologies.

Respirable Suspended Particulate Matter (RSPM)

- Respirable Suspended Particulate Matter (RSPM), also known as fine particulate matter (PM2.5), refers to tiny particles suspended in the air that are small enough to be inhaled into the respiratory system.
- RSPM includes particles with a diameter of 2.5 micrometers or smaller, which can penetrate deep into the lungs and even enter the bloodstream, leading to respiratory and cardiovascular problems.
- Sources of RSPM include vehicle emissions, industrial processes, construction activities, agricultural operations, and biomass burning.
- Exposure to high levels of RSPM is associated with increased risks of respiratory illnesses, asthma attacks, heart disease, and premature death.

Fly Ash

- Fly ash is a fine powder consisting of spherical particles that are produced as a byproduct of coal combustion in power plants.
- It is carried up the chimney with flue gases and captured by electrostatic precipitators or baghouses to prevent it from being released into the atmosphere.
- Fly ash contains various pollutants such as heavy metals, including arsenic, lead, and mercury, which can pose risks to human health and the environment if not properly managed.
- India's domestic coal reserves have a high ash content of generally 25 to 45%.
- Fly ash is commonly used in construction materials, such as concrete, cement, and asphalt, as a partial replacement for Portland cement, providing economic and environmental benefits by reducing the need for virgin materials and landfill disposal.

MoEFCC Notification on Fly Ash (2023)

- The MoEFCC notification on fly ash issued in December 2022, with amendments in January 2023, aimed to clarify and enforce stricter regulations regarding the utilization of fly ash, a byproduct of coal combustion in thermal power plants.

Objectives:

- **Increase fly ash utilization:** Encourage complete utilization of fly ash to minimize environmental impacts associated with landfilling and disposal.
- **Promote sustainable use:** Encourage the use of fly ash in various applications like construction materials, reducing reliance on conventional resources.
- **Improve compliance:** Enhance enforcement mechanisms through stricter penalties for non-compliance.

Key points:

- **Utilization targets:** Thermal power plants are mandated to achieve 100% fly ash utilization within three to five years, depending on their current utilization rate.
- **Previous price cap on fly ash bricks has been removed:** The new notification states that the cost of fly ash bricks will be determined based on the Department Schedule Rates (DSR) of the Central Public Works Department (CPWD) or the concerned State Public Works Department (PWD). The removal of the price cap on fly ash bricks has raised **concerns** among manufacturers, potentially making them **less competitive** compared to traditional bricks.
- **Legacy ash utilization:** The utilization of legacy ash (already accumulated) is not required in areas where reclamation has been undertaken with greenbelts or plantations.
- **Exemption for renewable energy plants:** Setting up solar and wind power plants within the ash pond area can exempt thermal power plants from fly ash utilization requirements.

Indoor Air Pollution

Indoor air pollution refers to the presence of harmful contaminants or pollutants indoors that can adversely affect human health. These pollutants can originate from various sources within buildings and have significant health implications, particularly when individuals are exposed to them over extended periods.

Sources of Indoor Air Pollution

- **Combustion Appliances:** Stoves, heaters, fireplaces, and furnaces that use fuels such as wood, coal, gas, or oil can emit pollutants such as carbon monoxide (CO), nitrogen dioxide (NO_2), and particulate matter (PM) into the indoor air, especially in poorly ventilated spaces.
- **Tobacco Smoke:** Smoking tobacco indoors releases a complex mixture of harmful chemicals, including nicotine, tar, carbon monoxide, and volatile organic compounds (VOCs), which can linger in the air and pose health risks to both smokers and nonsmokers.

- **Building Materials:** Volatile organic compounds (VOCs) emitted from building materials, paints, adhesives, carpets, furniture, and cleaning products can contribute to indoor air pollution, leading to respiratory problems, allergies, and other health issues.
- **Biological Contaminants:** Mold, mildew, pollen, pet dander, dust mites, and other biological contaminants can accumulate indoors, especially in damp or poorly ventilated areas, leading to indoor air quality problems and exacerbating allergies and asthma.
- **Radon Gas:** Radon is a naturally occurring radioactive gas that can seep into buildings from the soil or groundwater beneath them. Prolonged exposure to elevated levels of radon indoors is associated with an increased risk of lung cancer.
- **Household Chemicals:** Cleaning products, pesticides, and other household chemicals can release toxic fumes and VOCs into the indoor air, especially when used improperly or in enclosed spaces without adequate ventilation.

Mitigation Measures for Indoor Air Pollution

Promotion of Clean Cooking Technologies

- Encourage the adoption of clean cooking technologies such as liquefied petroleum gas (LPG), biogas, electric stoves, and improved biomass cookstoves.
- Example: Pradhan Mantri Ujjwala Yojana (PMUY),which was launched in 2016, aims to provide clean cooking fuel to households below the poverty line.

Awareness and Behavior Change Campaigns

- Launch public awareness campaigns to educate households about the health risks associated with indoor air pollution and the benefits of using clean cooking technologies and proper ventilation practices.
- **Example:** 'Give It Up' campaign launched by the Hon'ble PM, encourages domestic LPG consumers, who can afford to pay the non-subsidized price for LPG, to voluntarily surrender their LPG subsidy.

Improving Ventilation

- Enhance ventilation in households through the installation of windows, vents, exhaust fans, and chimneys to remove indoor air pollutants and improve air circulation.
- **Example:** Organizations like the Indian Council of Medical Research (ICMR) and the National Institute of Occupational Health (NIOH) conduct research and pilot projects to develop cost-effective ventilation solutions for rural households.

Indoor Air Quality Monitoring

- Implement indoor air quality monitoring programs to assess pollutant levels in households and identify areas with high levels of indoor air pollution.
- **Example:** The National Clean Air Programme (NCAP) includes provisions for indoor air quality monitoring and management to address indoor air pollution alongside outdoor air pollution.

Smog

- Smog occurs when a large number of gas-phase molecules and particulate matter are emitted into the atmosphere, creating a visible haze.
- The term "smog" was first used in the early 1900s to describe a mix of smoke and fog.
- Photochemical smog is produced when sunlight reacts with nitrogen oxides and at least one volatile organic compound (VOC) in the atmosphere. Nitrogen oxides come from car exhaust, coal power plants, and factory emissions. VOCs are released from gasoline, paints, and many cleaning solvents. When sunlight hits these chemicals, they form airborne particles and ground-level ozone—or smog. Today, most of the smog we see is photochemical smog.

Winter Smog In Delhi

Winter smog in Delhi refers to a severe air pollution phenomenon characterized by the accumulation of pollutants, primarily fine particulate matter (PM2.5) and toxic gases, in the atmosphere during the winter months.

Causes

- **Stubble burning:** Stubble burning in neighboring states of Punjab, Haryana and Western UP releases large amounts of smoke and pollutants into the atmosphere, exacerbating air pollution in Delhi.
  - These are brought in by the north-westerly winds in the post monsoon season which accounts for 72% of Delhi's winter winds.
- **Vehicle Emissions:** Increased vehicular traffic, especially diesel vehicles, contributes to the release of pollutants such as nitrogen oxides (NOx), carbon monoxide (CO), and particulate matter (PM) into the air.
  - According to studies from IIT Delhi vehicular emissions contribute ~25% to Delhi's PM2.5 levels.
- **Industrial Pollution:** Emissions from industries, power plants, and construction activities add to the pollution load, especially when combined with unfavorable weather conditions.
- **Biomass Burning:** The use of biomass fuels for heating and cooking in households, especially in rural areas and unauthorized colonies, releases smoke and pollutants into the air.
- **Meteorological Factors:** Weather conditions such as low temperatures, stagnant air masses, and low wind speeds during the winter months exacerbate the accumulation of pollutants, leading to the formation of a thick layer of smog over the city.

- **Temperature inversion:** Due to temperature inversion pollutants from stubble burning, vehicle emissions, industrial emissions, and other sources accumulate in the lower atmosphere and form a thick layer of smog.

{**Temperature inversion** is a phenomenon that occurs when the air temperature increases with altitude, instead of decreasing as usual. This creates a layer of warm air above a layer of cold air, trapping the pollutants near the ground}

Pollution Dome

- Pollution Dome refers to a mass of polluted air in and above a city or industrial complex which is prevented from rising due to **temperature inversion** above it.
- The widespread urbanization coupled with **Urban Heat Island Effect** leads to a rise in pollution domes over the Indian subcontinent.

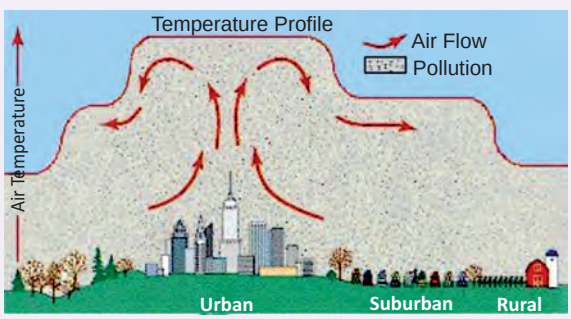


Fig. 9.2: Pollution Dome

Addressing air pollution requires a comprehensive and concerted effort from governments, industries, communities, and individuals. Moving forward, continued investment in clean energy, sustainable urban planning, international collaboration, and research and innovation will be essential to achieve significant and lasting improvements in air quality for current and future generations.

WATER POLLUTION

Water pollution refers to the contamination of water bodies such as lakes, rivers, oceans, groundwater, and aquifers, making them unsuitable or harmful for various uses, including drinking, swimming, fishing, and agriculture. It occurs when pollutants are discharged or introduced into water sources, either directly or indirectly, by human activities or natural processes.

Measurement of Water Pollution

Measurement of water pollution involves assessing the quality of water by quantifying the presence and concentration of various pollutants.

- **Sampling:** Water samples are collected from different water bodies, such as rivers, lakes, oceans, and groundwater sources, using specialized equipment and sampling protocols to ensure representative and accurate measurements.
- **Parameter Selection:** Relevant parameters and pollutants to be measured are identified based on the specific characteristics of the water body and potential sources of pollution. Common parameters include pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nutrients (nitrogen and phosphorus), heavy metals, pathogens Faecal coliform, helminthic eggs and specific pollutants of concern.
- **Analysis:** Laboratory analysis is conducted on the collected water samples to measure the concentration of pollutants using analytical techniques such as spectrophotometry, chromatography, mass spectrometry, and microbial culture methods. Standardized methods and protocols are followed to ensure consistency and reliability of results.
- **Data Interpretation:** The measured concentrations of pollutants are compared to water quality standards, guidelines, or regulatory limits established by local, national, or international authorities to assess the extent of pollution and potential risks to human health and the environment. Data interpretation may also involve trend analysis, spatial mapping, and risk assessment to identify patterns, sources, and hotspots of pollution.
- **Reporting and Communication:** Results of water quality monitoring are compiled into reports and communicated to relevant stakeholders, including government agencies, policymakers, industries, communities, and the public, to inform decision-making, prioritize pollution control measures, and raise awareness about water pollution issues.

Parameter	Description	Measurement Unit	Indicator of
Dissolved Oxygen (DO)	Amount of oxygen dissolved in water, crucial for aquatic life.	mg/L or % saturation ▪ DO < 8.0 mg/L is contaminated. ▪ DO < 4.0 mg/L is highly polluted.	Water quality, aquatic health
Biochemical Oxygen Demand (BOD)	Measure of oxygen consumed by microorganisms during organic matter degradation in water.	mg/L	Organic pollution Higher value of BOD → low DO content of water.
Chemical Oxygen Demand (COD)	Measure of oxygen required to chemically oxidize organic and inorganic substances in water.	mg/L	Total organic and oxidizable pollutants

Sources of Water Pollution

Aspect	Point Sources	Non-Point Sources
Definition	Specific, identifiable locations where pollutants enter water bodies directly	Diffuse and widespread, making them challenging to pinpoint to specific locations
Examples	Industrial wastewater discharge pipes, sewage treatment plants, oil spills from ships or pipelines, specific agricultural operations such as feedlots or poultry farms	Agricultural runoff containing pesticides and fertilizers, urban runoff carrying pollutants from roads, parking lots, and rooftops, erosion of soil and sediment from construction sites or deforested areas, atmospheric deposition of pollutants such as heavy metals and airborne contaminants
Monitoring and Regulation	Relatively easier to monitor and regulate compared to non-point sources because they originate from discrete and identifiable sources	More challenging to monitor and regulate due to their diffuse and variable nature
Management Approach	Typically involves direct regulation and enforcement of discharge standards and permits	Requires broader management approaches such as watershed management, land use planning, and implementation of best management practices

Agricultural Sources

- **Pesticide Contamination:** Pesticides used to control pests and diseases in crops can leach into groundwater or runoff into surface water, contaminating drinking water sources and harming aquatic organisms. Persistent pesticides can accumulate in the environment over time, posing long-term risks to ecosystems.
- **Nutrient Runoff:** Excessive amounts of nutrients such as nitrogen and phosphorus from agricultural runoff, sewage discharges, and urban stormwater runoff can lead to eutrophication, a process where excessive plant growth depletes oxygen levels in water bodies, causing fish kills and harmful algal blooms.
- **Sediment Erosion:** Soil erosion from deforestation, construction activities, and agricultural practices can result in sediment runoff, which clouds water and disrupts aquatic ecosystems by smothering habitats, reducing sunlight penetration, and clogging fish gills.

Chemical Pollutants

- Industrial chemicals, pesticides, fertilizers, heavy metals, and pharmaceuticals are examples of chemical pollutants that can contaminate water bodies through runoff, industrial discharges, or improper waste disposal.

Biological Pollutants

- Pathogens such as bacteria, viruses, and parasites from human and animal waste can contaminate water sources, leading to waterborne diseases such as cholera, typhoid, and dysentery.

Toxic Substances

- Hazardous substances such as heavy metals (e.g., mercury, lead), PCBs, dioxins, and volatile organic compounds (VOCs) can accumulate in water bodies, posing serious risks to human health and the environment through bioaccumulation and biomagnification in the food chain.

Water Pollution Status

Global Water Pollution

- **Human health:** Waterborne diseases claim an estimated 1.4 million lives annually, primarily children under five.
- **Ecosystem damage:** Polluted water harms aquatic life, disrupts ecosystems, and reduces biodiversity.
- **Economic costs:** Water crisis threatens $58 trillion in economic value, food security and sustainability.
- **2 billion tons** of wastewater are discharged into the world's water bodies daily, mostly **untreated**.
- **Over 80%** of wastewater globally goes **untreated**, posing a significant threat to water quality and public health.
- Up to **5.5 billion** people worldwide could be exposed to **polluted water** by 2100, a modelling study has found.

Water Pollution in India

- The **Central Pollution Control Board (CPCB)** reports that **over half** of India's monitored river stretches are polluted.
- A 2019 World Bank report estimates that water pollution costs India **₹3.75 trillion ($80 billion)** annually.
- **70%** of India's surface water is estimated to be polluted, exceeding safe limits for drinking and aquatic life.
- According to a report published by the Central Pollution Control Board (CPCB) in 2021, India's current water treatment capacity is **27.3%** and the sewage treatment capacity is **18.6%.**

Causes of Water Pollution

- **Industrial Activities:** Discharges of untreated or inadequately treated industrial wastewater containing heavy metals, chemicals, solvents, and other pollutants from manufacturing processes contribute significantly to water pollution. Industries such as chemical manufacturing, mining, oil refining, and textile production are major sources of industrial pollution.
- **Urbanization and Urban Runoff:** Urban areas generate pollution through various activities such as sewage discharge, stormwater runoff from streets, parking lots, and rooftops, improper disposal of household chemicals and waste, and leakage from underground storage tanks. Urban runoff can carry pollutants such as heavy metals, oil and grease, pesticides, and pathogens into water bodies.
- **Agricultural Practices:** Runoff from agricultural lands containing fertilizers, pesticides, herbicides, and animal waste is a significant source of water pollution. The use of chemical fertilizers and pesticides in farming contributes to nutrient pollution, eutrophication, and contamination of groundwater and surface water.
- **Inadequate Sanitation and Wastewater Management:** Improper disposal of human waste and inadequately treated sewage from domestic, commercial, and municipal sources can contaminate water bodies with pathogens, nutrients, and organic matter, leading to waterborne diseases, algal blooms, and oxygen depletion.
- **Deforestation and Soil Erosion:** Deforestation, land clearing, and unsustainable land use practices such as overgrazing and improper agricultural practices can increase soil erosion, sediment runoff, and nutrient loss, which degrade water quality, disrupt aquatic habitats, and impair ecosystem functions.
- **Atmospheric Deposition:** Airborne pollutants such as heavy metals, acid rain, volatile organic compounds (VOCs), and airborne contaminants from industrial activities can deposit into water bodies through rainfall, snowmelt, and atmospheric deposition, contributing to contamination of surface water and groundwater.
- **Natural Events:** Natural events such as algal blooms, volcanic eruptions, and earthquakes can release pollutants into water bodies and disrupt aquatic ecosystems. For example, algal blooms can produce toxins harmful to aquatic life and human health, while volcanic eruptions can release ash, gases, and heavy metals into water bodies.

Harmful Effects of Water Pollution

- **Health Risks:** Contaminated water can pose significant health risks to humans through ingestion, inhalation, or dermal contact with pollutants. Waterborne pathogens such as bacteria, viruses, and parasites can cause waterborne diseases such as cholera, typhoid, dysentery, and gastrointestinal infections.
- **Ecological Impacts:** Water pollution can disrupt aquatic ecosystems, leading to declines in biodiversity, loss of habitat, and degradation of aquatic habitats such as rivers, lakes, wetlands, and coral reefs. It creates vast dead zones in aquatic habitats caused by nutrient pollution which causes algal bloom which increases BOD.
- **Eutrophication:** Excessive nutrient pollution, particularly nitrogen and phosphorus from sources like agricultural runoff and sewage discharge, can lead to eutrophication, a process where water bodies become excessively enriched with nutrients, promoting the rapid growth of algae and aquatic plants.
- **Contamination of Drinking Water:** Water pollution can contaminate drinking water sources, posing risks to public health and safety. Contaminants such as pathogens, heavy metals, pesticides, and chemical pollutants (e.g. Arsenic, Fluoride, Nitrate) can enter drinking water supplies through surface water and groundwater sources, leading to outbreaks of waterborne diseases, chemical poisoning, and long-term health problems.
- **Economic Costs:** Water pollution can have significant economic costs, including expenses related to healthcare treatment for waterborne illnesses, loss of productivity due to sick days, impacts on tourism and recreational activities, damage to fisheries and aquaculture industries, and costs associated with water treatment and pollution cleanup efforts.

Measures to Control Water Pollution

Global Initiatives

- **United Nations (UN) Water Summit on Groundwater (GW) 2022**
  - It was a global summit organised by the UN-Water, UNESCO, and the International Groundwater Resources Assessment Centre.
  - The event aims to increase awareness about groundwater conservation and shed light on the opportunities and challenges associated with its management.
  - It was a culmination of the "Groundwater: Making the invisible visible" campaign led by UN-Water throughout 2022.

- The discussions focused on the five pillars of the SDG 6 Global Acceleration Framework:
  - Data and information; Capacity development
  - Innovation; Finance; Governance
- The campaign emphasized the pivotal role of groundwater in addressing poverty, food and water insecurity, and other socio-economic development challenges.

❑ **Water Convention**

- The Water Convention, formally known as the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, is an international treaty adopted in 1992 under the auspices of the United Nations Economic Commission for Europe (UNECE).
- The convention aims to promote cooperation among countries in the management and protection of transboundary water resources, including rivers, lakes, and aquifers.
- It establishes principles and mechanisms for transboundary water cooperation, including data exchange, joint monitoring, and dispute resolution.

India's Initiatives

❑ **Legislation and Regulations:** Implementation of laws such as the Water (Prevention and Control of Pollution) Act, 1974, and the Environment (Protection) Act, 1986, to regulate and control water pollution.

❑ **River Rejuvenation Programs:** Initiatives such as the Namami Gange project aimed at cleaning and rejuvenating the Ganges river, which is one of the most polluted rivers in India.

❑ **Namami Gange:**

- The Indian government's flagship program aims to rejuvenate the Ganges River by implementing various pollution control measures, including sewage treatment plants, river surface cleaning and awareness campaigns to prevent pollution.

❑ **National River Conservation Programme (NRCP):** This central government program aims to improve the water quality of major rivers through pollution abatement measures, afforestation, and community participation.

❑ **Jal Jeevan Mission:** This flagship mission aims to provide safe and adequate drinking water to every rural household through individual household tap connections, addressing water quality concerns at the source.

Arth Ganga

❑ **"Arth Ganga"** is a concept introduced by the Indian government as part of the **Namami Gange project.**

❑ It aims to **restore the economic and ecological prosperity of the Ganges River basin** while focusing on sustainable development and the rejuvenation of river-dependent communities.

❑ Arth Ganga envisions leveraging the river's potential to support livelihoods, promote tourism, and facilitate sustainable agriculture and industrial practices, all while ensuring the river's ecological health is preserved.

❑ The concept emphasizes **community participation, scientific research, and technological innovations** to achieve its goals and transform the Ganges basin into a thriving and sustainable socio-economic corridor.

Challenges in Measures Taken to Control Water Pollution

❑ **Complexity of Pollution Sources:** Water pollution stems from a multitude of sources, including both point sources and non-point sources such as industrial discharges, agricultural runoff, sewage effluent, and urban stormwater runoff. Addressing pollution from diverse sources requires integrated management approaches and collaboration across sectors.

- **Example:** In urban areas, pollution from industrial activities, sewage systems, and runoff from roads and construction sites contribute to water pollution in rivers and lakes, requiring coordinated efforts to control pollution from multiple sources.

❑ **Lack of Infrastructure and Resources:** Inadequate infrastructure for wastewater treatment and limited financial resources hamper efforts to control water pollution, particularly in developing countries. Insufficient funding for pollution control projects and maintenance of treatment facilities impedes progress in reducing pollution.

❑ **Emerging Contaminants and Technologies:** Emerging contaminants, such as pharmaceuticals, microplastics, and per- and polyfluoroalkyl substances (PFAS), present challenges for traditional water treatment methods and regulatory frameworks. Identifying and regulating emerging contaminants requires ongoing research and adaptive management strategies.

Way Forward

❑ **Regulations and Standards:** Implementation of stringent water quality standards and regulations to limit the discharge of pollutants into water bodies.

- For example, the Water (Prevention and Control of Pollution) Act, 1974, and the Environment (Protection) Act, 1986, regulate water pollution and provide the legal framework for pollution control in India.

❑ **Unconventional Water Resources:** Unconventional water resources refer to alternative or non-traditional sources of water that can supplement conventional freshwater sources such as rivers, lakes, and groundwater.

- Examples of unconventional water resources include desalinated seawater, recycled wastewater (reclaimed water), rainwater harvesting, fog harvesting, and brackish groundwater.

- **Wastewater Treatment:** Establishment of wastewater treatment plants (WWTPs) to treat domestic, industrial, and agricultural wastewater before discharge.
- **Effluent Standards for Industries:** Enforcement of effluent discharge standards for industries to control the release of pollutants into water bodies. Central Pollution Control Board (CPCB) sets effluent standards for various industries, such as the textile, chemical, and pharmaceutical sectors, to ensure compliance with pollution control measures.
- **Stormwater Management:** Implementation of stormwater management practices to control runoff and prevent the contamination of surface water bodies.
- **Rural Sanitation Programs:** Promotion of rural sanitation programs to improve access to clean water and sanitation facilities in rural areas.
- **Community Participation and Awareness:** Programs like the Jal Shakti Abhiyan promote community-led initiatives for water conservation, rainwater harvesting, and rejuvenation of water bodies, fostering a sense of ownership and responsibility among communities.
- **Capacity of Urban Local Bodies:** Enhancing capacity of ULBs to build economically sustainable models of sewage treatment.

One Water Approach

- **One water approach**, also known as **integrated water management or holistic water management,** emphasizes the **interconnectedness** of various water resources, including surface water, groundwater, and rainwater, as well as the water cycle as a whole.
  - This approach recognizes that all water sources are interrelated and should be managed collectively to achieve sustainable and equitable water management outcomes.
- The one water approach promotes **integrated planning, decision-making, and management practices** that consider the entire water cycle, from collection and treatment to distribution, consumption, and reuse.
  - It seeks to **optimize water use efficiency, minimize waste, and enhance resilience** to water-related challenges such as **scarcity, pollution, and climate change impacts.**

Fig. 9.3: All Water is One Water

Key Principles of the One Water Approach

- **Integrated Management:** Recognizing the interconnectedness of water resources and coordinating management efforts across different sectors and stakeholders to achieve multiple benefits and minimize trade-offs.
- **Sustainability:** Promoting sustainable water use practices that balance environmental, social, and economic considerations to meet the needs of present and future generations.
- **Resilience:** Building resilience to water-related risks and uncertainties by diversifying water sources, enhancing infrastructure reliability, and implementing adaptive management strategies.
- **Equity and Inclusivity:** Ensuring equitable access to water resources and involving diverse stakeholders, including marginalized communities and indigenous peoples, in decision-making processes.
- **Innovation and Collaboration**: Fostering innovation, technology adoption, and collaboration between government agencies, private sector entities, civil society organizations, and academia to address water challenges effectively.

OTHER ISSUES RELATED TO WATER POLLUTION

Ground Water Pollution

Groundwater Potential in India

- India is the largest user of ground water with 1/4th of total global withdrawal.
- As per the Dynamic Ground Water Resources Assessment carried out by CGWB and state governments in 2020, annual utilisable groundwater resources in India are 436 BCM and the annual extractable groundwater resources are 397 BCM.

- The annual groundwater extraction for all uses is 245 BCM, out of which 217 BCM (89 per cent) is for irrigation use and 27 BCM (11 per cent) is for domestic uses.
- Uttar Pradesh has the highest net annual groundwater availability (72 BCM) while Delhi has the least (0.32 BCM).
- At 39 million hectares (67% of its total irrigation), India has the world's largest groundwater well-equipped irrigation system.

Groundwater Pollution Status

- Arsenic pollution in groundwater
  - Groundwater arsenic contamination in India can be subdivided into two main regions: the alluvial regions of West Bengal, Bihar, Jharkhand, Uttar Pradesh, Assam, and Punjab, and the hard-rock regions of Karnataka and Chhattisgarh.
  - Alluvial aquifers constitute the primary source (90%) of arsenic contamination in India.
- **Fluoride** contamination in groundwater
  - The pooled concentration of fluoride in India's groundwater is around 2.37 mg/L, which is higher than the World Health Organization (WHO) and national standards limit of 1.5 mg/L. In rural areas, fluoride concentration is 1.85 times higher than in urban areas
  - Most affected states are : Rajasthan, Andhra Pradesh, Telangana, Tamil Nadu, Gujarat, West Bengal, Southern Punjab, Karnataka, Madhya Pradesh, Southern Haryana.

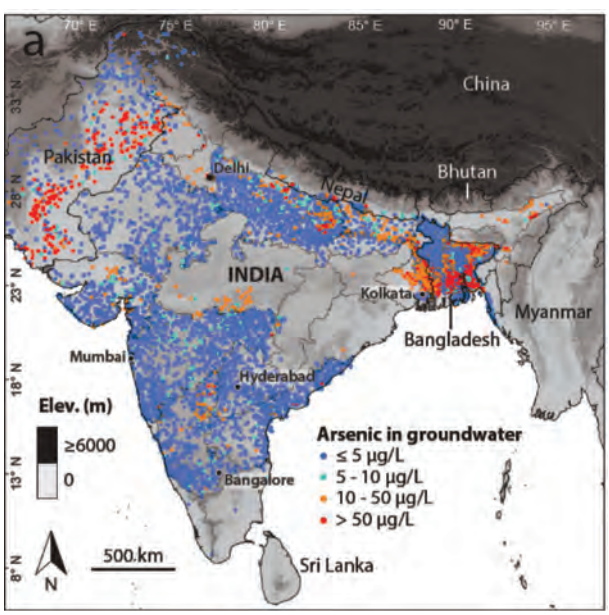


Fig. 9.4

- The groundwater contamination reported by the Central Ground Water Board (CGWB) is mostly geogenic in nature
- According to the NITI Aayog's Composite water management index- about 70 per cent of India's water resources are polluted.

Causes of Groundwater Pollution

Natural Causes

- **Geological Sources:** Naturally occurring minerals and elements in geological formations can leach into groundwater, leading to contamination. For example, arsenic, fluoride, and radon are naturally present in some geological formations and can dissolve into groundwater, causing pollution. In regions with high arsenic content in geological formations, such as parts of West Bengal and Bangladesh, natural arsenic contamination of groundwater is a significant concern.
- **Microbial Activity:** Natural microbial processes can contribute to groundwater pollution. For instance, bacteria such as Escherichia coli (E. coli) and viruses can infiltrate groundwater from sources like septic systems and animal waste, contaminating it with pathogens.

Anthropogenic Causes

- **Industrial Activities:** Industries discharge various pollutants into the environment, which can infiltrate into groundwater. Chemicals, heavy metals, and organic compounds from industrial processes contaminate groundwater.
- **Agricultural Practices:** The use of chemical fertilizers, pesticides, and herbicides in agriculture can contribute to groundwater pollution. Excess nutrients like nitrates and phosphates from fertilizers can leach into groundwater, leading to contamination.
- **Urbanization and Human Settlements:** Urbanization brings challenges related to wastewater disposal, sewage, and solid waste management, which can pollute groundwater. Improperly constructed or maintained sewage systems, septic tanks, landfills, and waste disposal sites can contaminate groundwater with pathogens, heavy metals, and organic pollutants.
- **Landfills and Waste Disposal:** Improper disposal of solid waste and hazardous materials in landfills can lead to leachate formation. For example, in cities like Bangalore and Chennai, poorly managed landfills have resulted in groundwater pollution with heavy metals, organic pollutants, and pathogens.

Consequences

- **Health Impacts:** Contaminated groundwater poses serious health risks, including waterborne diseases, cancer, and neurological disorders. For example, in areas with high arsenic contamination like West Bengal's Gangetic plains, residents suffer from arsenic-induced health problems.
- **Environmental Degradation:** Groundwater pollution disrupts ecosystems and biodiversity. Contaminants can accumulate in aquatic organisms, leading to bioaccumulation and biomagnification. For instance, in Kerala's Periyar river basin, groundwater pollution from industrial activities has harmed aquatic life.

- **Socio-economic Effects:** Polluted groundwater affects livelihoods, agriculture, and access to safe drinking water, particularly for marginalized communities. For instance, in parts of Uttar Pradesh and Bihar, high fluoride levels in groundwater impact crop yields and human health.

Mitigation Measures

- **Regulatory Framework:** Strengthening enforcement of environmental regulations and implementing stringent penalties for polluters is crucial. The National Green Tribunal (NGT) in India has played a significant role in addressing groundwater pollution cases.
- **Water Quality Monitoring:** Regular monitoring of groundwater quality is essential to identify contamination hotspots and take timely corrective actions. Initiatives like the Central Ground Water Board's groundwater monitoring program help assess water quality across the country.
- **Sustainable Practices:** Promoting sustainable agriculture practices, such as organic farming and integrated pest management, reduces the use of chemical inputs and mitigates groundwater pollution. Initiatives like the Paramparagat Krishi Vikas Yojana (PKVY) support organic farming in India.
- **Water Treatment Technologies:** Investing in water treatment infrastructure, such as reverse osmosis plants and activated carbon filters, helps remove contaminants from groundwater. For instance, community-based arsenic removal units have been deployed in affected areas like West Bengal.
- **Central Ground Water Authority (CGWA):** CGWA is constituted under Section 3 (3) of the Environment (Protection) Act, 1986 to develop and disseminate technologies, and monitor and implement national policies for the Scientific and Sustainable development and management of India's Ground Water Resources, including their exploration, assessment, conservation, augmentation, protection from pollution and distribution, based on principles of economic and ecological efficiency and equity.

Algal Bloom

- An algal bloom is a rapid increase in the population of algae (microscopic or macroscopic) in water bodies, often fueled by high levels of nutrients such as nitrogen and phosphorus from sources like agricultural runoff or untreated sewage.
- Algal blooms can lead to the discoloration of water, depletion of oxygen levels, release of toxins harmful to aquatic life and humans, and the disruption of aquatic ecosystems.

Eutrophication

- Eutrophication is a process in which water bodies become excessively enriched with nutrients, particularly nitrogen and phosphorus, leading to accelerated growth of algae and aquatic plants.
- This excessive growth can result in algal blooms, oxygen depletion (hypoxia), and degradation of water quality, harming aquatic ecosystems and compromising water resources for human use.

Mercury Pollution

- Mercury pollution refers to the release of mercury into the environment, where it can accumulate in water bodies and become methylated by bacteria, leading to the formation of highly toxic methylmercury.
- Mercury is a highly toxic element; there is no known safe level of exposure to mercury.
- Methylmercury biomagnifies in the food chain, posing risks to aquatic organisms and humans who consume contaminated fish and seafood. Mercury pollution primarily originates from industrial processes, coal combustion, and artisanal and small-scale gold mining.

Oxygen Stratification

- Oxygen stratification occurs when water bodies, such as lakes or reservoirs, develop distinct layers of water with different oxygen concentrations.
- This stratification can result from factors such as temperature gradients, nutrient inputs, and water flow patterns.
- In stratified water bodies, oxygen levels may be higher near the surface but decrease with depth, leading to hypoxic or anoxic conditions in deeper layers, which can be detrimental to aquatic organisms and ecosystems.

Water pollution remains a critical global issue with far-reaching environmental, social, and economic implications. As contamination of water bodies continues to threaten ecosystems, biodiversity, and human health, urgent action is needed to address the root causes of water pollution and implement effective mitigation measures.

This requires collaborative efforts from governments, industries, communities, and individuals to regulate pollution sources, improve waste management practices, and promote sustainable water use and conservation.

By prioritizing water quality protection, investing in pollution control technologies, and fostering awareness and stewardship of water resources, we can realize SDG 14('Life Below Water') and 15(Life on Land') and ensure a sustainable and healthy environment for all.

MARINE POLLUTION

Marine pollution refers to the contamination of the marine environment, including oceans, seas, coastal areas, and estuaries, by various pollutants originating from human activities and natural processes.

Marine Pollution Status

Global Marine Pollution

- An estimated **8 Million tons of plastic** enters our oceans **every year.**
- There are **5.25 trillion pieces of plastic waste** estimated to be in our **oceans.**
- **269,000 tons float, 4 billion microfibers per km²** dwell below the surface.
- **70%** of our debris sinks into the ocean's ecosystem, **15%** floats, and **15%** lands on our beaches.

Marine Pollution in India

- Some **15,343 tonnes** of waste dumped in the South Asian seas daily are generated from **60 major Indian cities**, according to **UNEP.**
- An average of **0.98 metric tonnes** of trash per km stretch of coastline, averaging a weight concentration of **0.012 kilograms per metre square,** accumulated along the Indian coastline, noted Swachh Sagar, Surakshit Sagar campaign, 2022.

Causes of Marine Pollution

- **Industrial Discharges:** Industrial activities such as manufacturing, mining, oil and gas exploration, and shipping can release pollutants such as heavy metals, chemicals, oil, and wastewater into marine ecosystems through direct discharges, spills, and runoff from industrial facilities and ports.
- **Urban Runoff:** Urban areas contribute to marine pollution through stormwater runoff carrying pollutants such as oil, grease, heavy metals, pesticides, fertilizers, sewage, and litter from streets, parking lots, and residential areas, which can flow into rivers, streams, and coastal waters.
- **Agricultural Runoff:** Agriculture is a significant source of marine pollution due to the runoff of agricultural chemicals such as fertilizers, pesticides, herbicides, and animal waste from farmland into nearby water bodies, leading to nutrient pollution, eutrophication, and contamination of marine ecosystems.
- **Waste Disposal:** Improper disposal of solid waste, including plastics, packaging materials, electronic waste, and household garbage, can result in marine debris and litter that accumulate in oceans and coastal areas, posing risks to marine life through ingestion, entanglement, and habitat degradation.
- **Sewage Discharges:** Untreated or inadequately treated sewage discharges from municipal wastewater treatment plants, sewage overflows, and combined sewer overflows can introduce pathogens, nutrients, pharmaceuticals, and other contaminants into marine waters, leading to waterborne diseases and pollution of recreational and shellfish harvesting areas.
- **Ballast Water from ships:** It alters temperature as well as introduce pollutants in the ocean.
- **Oil Spills:** Offshore mining of oil and natural gas as well as seas being the major route for their trade through ships which many times due to accidents cause oil spills.
- **Shrimp Farming:** It has emerged as one of the major cause of marine pollution.

Harmful Effects of Marine Pollution

- **Harm to Marine Life:** Marine pollution can harm marine organisms such as fish, seabirds, marine mammals, sea turtles, and coral reefs through direct toxicity, ingestion of pollutants, entanglement in marine debris, habitat destruction, and disruption of food chains and ecosystems.
- **Loss of Biodiversity:** Pollution can contribute to the loss of biodiversity in marine ecosystems by damaging critical habitats, reducing populations of sensitive species, altering community structures, and creating ecological imbalances that threaten marine biodiversity and ecosystem resilience.
- **Contamination of Seafood:** Pollutants such as heavy metals, persistent organic pollutants (POPs), and harmful algal toxins can accumulate in marine organisms and seafood, posing risks to human health through the consumption of contaminated fish and shellfish.
- **Damage to Coastal Areas:** Marine pollution can degrade coastal ecosystems, including mangrove forests, seagrass beds, salt marshes, and coral reefs, which provide important ecological services such as shoreline protection, habitat for marine species, and support for fisheries and tourism.
- **Impacts on Human Health:** Marine pollution can pose risks to human health through exposure to contaminated seafood, recreational waters, and coastal environments, leading to waterborne diseases, respiratory problems, skin irritation, and other health issues.

Measures to Control Marine Pollution

Global Initiatives

- **Regulatory Frameworks:** International agreements such as MARPOL (International Convention for the Prevention of Pollution from Ships) set standards for ship pollution control.

MARPOL Convention

The MARPOL Convention, short for the International Convention for the Prevention of Pollution from Ships, is a key international treaty aimed at preventing marine pollution from ships. It was adopted by the International Maritime Organization (IMO) in 1973 and later amended by the Protocol of 1978.

- **Marine Protected Areas (MPAs):**
  - Many countries have established MPAs to conserve marine ecosystems and reduce human impacts, including pollution. MPAs restrict certain activities like fishing and industrial development to protect sensitive marine habitats. Kunming-Montreal Global Biodiversity Framework aims as declaring 30 % pf marine area as protected area by 2030.
- **International Maritime Organization (IMO) Regulations:**
  - The IMO sets global standards and regulations to prevent marine pollution from ships, including measures to reduce air emissions, control sewage discharge, and manage oily waste and ballast water.
  - **The High Seas Treaty(2023):** Also being called Paris agreement of the oceans, this treaty will help tackle marine pollution in high seas which constitute over 70 percent of the oceans
- **Global Plastic Pollution Reduction Initiatives:**
  - Various international initiatives, such as the United Nations Environment Programme's Clean Seas Campaign and the Ellen MacArthur Foundation's New Plastics Economy initiative, aim to reduce plastic pollution in oceans through awareness, policy advocacy, and industry engagement.
- **Ocean Cleanup Technologies:**
  - Organizations like The Ocean Cleanup develop and deploy technologies to remove plastic debris from oceans.
  - Projects include passive cleanup systems, such as floating barriers, and innovative approaches to recycling ocean plastics.
- **Integrated Coastal Zone Management (ICZM):**
  - ICZM approaches promote sustainable management of coastal areas, balancing economic development with environmental conservation and pollution prevention.
    - ICZM plans incorporate measures to reduce pollution from coastal development, tourism, and shipping activities.

Other Major Global Initiatives to Reduce Marine Pollution

- **Global Partnership on Marine Litter (GPML):** Launched in 2012 at the Earth Summit, aimed at developing policies to reduce marine litter and pollution. 65 signatories to the Manila Declaration reaffirmed their commitment to tackle marine pollution.
- **G7 Summit:** Acknowledged microplastic risks in the 2015 Leaders' Declaration during the summit in Bavaria, Germany.
- **GloLitter Partnerships Project:** Joint initiative by the IMO and FAO targeting the prevention and reduction of marine plastic litter.
- **London Convention, 1972:** Enacted to control marine pollution by regulating waste dumping into the sea, with subsequent protocols like the London Protocol and MARPOL.
- **World Environment Day, 2018:** Hosted in India, world leaders pledged to "Beat Plastic Pollution" and eliminate its use.

India's Initiatives

- **Coastal Regulation Zone (CRZ) Rules:** India's CRZ rules regulate activities along the coast to protect coastal ecosystems and prevent marine pollution. These rules restrict industrial activities, construction, and waste disposal in sensitive coastal areas to minimize pollution.
- **Plastic Waste Management Rules:** The Plastic Waste Management Rules, 2016, regulate the production, use, and disposal of plastic products to prevent plastic pollution in marine environments. These rules promote plastic waste recycling and impose restrictions on single-use plastics.
- **Oil Pollution Prevention:** India has implemented measures to prevent oil spills and respond to maritime accidents through the National Oil Spill Disaster Contingency Plan (NOS-DCP) and the establishment of Oil Spill Response Centres (OSRCs) along the coast.

Challenges in Measures taken to Control Marine Pollution

- **Transboundary Nature:** Pollution from land-based sources, such as industrial discharges and agricultural runoff, can flow into rivers and eventually reach the ocean, transcending national boundaries and complicating pollution management.
  - **Example:** According to a study by the National Institute of Oceanography, approximately 1.2 billion liters of untreated sewage and industrial waste are discharged into the Ganges daily, contributing to marine pollution beyond India's territorial waters into the Bay of Bengal.
- **Limited Enforcement and Monitoring:** Inadequate enforcement of existing regulations and limited monitoring infrastructure hinder efforts to detect and prevent marine pollution.
  - **Example:** In Southeast Asia, the lack of enforcement of regulations leads to extensive plastic pollution in marine environments.
    - According to a report by Ocean Conservancy, five Asian countries (China, Indonesia, the Philippines, Thailand, and Vietnam) are responsible for more than 55% of plastic waste leaking into oceans annually due to inadequate waste management infrastructure and lax enforcement of regulations.
- **Complexity of Marine Ecosystems:** Marine ecosystems are complex and interconnected, making it challenging to assess the full extent of pollution impacts and implement targeted mitigation measures.

- **Example:** Pollution in marine environments can have cascading effects on marine species, habitats, and food webs, making it challenging to predict and manage ecosystem responses to pollution events.

- **Technological Limitations:** Implementing advanced technologies for pollution control, such as oil spill response equipment and marine debris cleanup technologies, can be costly and logistically challenging.
  - Cleaning up large-scale oil spills in remote or deep-sea locations poses significant technical challenges, requiring specialized equipment and expertise.
- **Lack of Public Awareness:** Limited public awareness about marine pollution and its impacts may lead to apathy or indifference towards pollution prevention efforts.
  - **Example:** In coastal communities in Indonesia, limited public awareness about the harmful effects of plastic pollution leads to widespread use of single-use plastics and improper waste disposal practices.
    - According to the United Nations Environment Programme (UNEP), Indonesia is the world's second-largest contributor to marine plastic pollution, with an estimated 1.29 million tonnes of plastic waste entering the ocean annually.

      {**China** is the **world's largest** contributor to marine plastic pollution.}
- **Globalization and Shipping:** Global shipping activities contribute significantly to marine pollution through accidental oil spills, illegal ballast discharges, and emissions of air pollutants.
  - **Example:** The discharge of ballast water from international shipping vessels introduces invasive species into marine ecosystems, leading to ecological disruption.
    - According to the International Maritime Organization (IMO), ballast water is a primary vector for the introduction of invasive species, with an estimated 7,000 different species transported daily via ballast water worldwide.

Way Forward

- **Waste Management:** Improving waste management practices on land to prevent land-based pollutants such as plastics, chemicals, and sewage from reaching the ocean. This includes implementing proper waste disposal and recycling programs, as well as promoting the use of biodegradable and eco-friendly materials.
- **Sewage Treatment:** Upgrading sewage treatment infrastructure to ensure that sewage is adequately treated before being discharged into coastal waters. Advanced treatment technologies can remove pollutants and pathogens from sewage, reducing the risk of contamination in marine environments.
- **Industrial Pollution Control:** Implementing pollution prevention measures in industries to reduce the discharge of toxic chemicals, heavy metals, and other pollutants into water bodies. This may involve using cleaner production techniques, implementing pollution control technologies, and enforcing emission standards.
- **Marine Spatial Planning:** Implementing marine spatial planning to manage human activities in coastal and marine areas effectively. By identifying sensitive marine habitats and regulating human activities such as shipping, fishing, and offshore development, marine spatial planning can help minimize the impacts of pollution on marine ecosystems.
- **Oil Spill Response:** Developing and implementing oil spill response plans to mitigate the environmental impacts of oil spills in marine environments. This includes measures such as containment, recovery, and cleanup of spilled oil, as well as restoration of affected habitats and wildlife.
- **Marine Protected Areas:** Establishing marine protected areas (MPAs) to conserve and protect marine ecosystems from pollution and other threats. MPAs can help safeguard sensitive habitats, promote biodiversity conservation, and regulate human activities to minimize pollution and disturbance.
- **Coordination:** Due to its trans boundary nature, coordination between countries to design and implement solutions jointly.
- **Green Shipping:** Promoting clean fuels in shipping industry which majorly rely on Diesel.
- **Common environmental Standards for deep sea mining:** In light of emerging technologies and pursuit of nations to mine deep sea for rare and precious minerals, it is wise to develop standards and strengthen implementation mechanism through UNCLOS especially for High Seas.

Other Issues Related to Marine Pollution

Dead Zone

- Dead Zones are areas in oceans, seas, or freshwater bodies where oxygen levels are severely depleted, leading to hypoxic or anoxic conditions that cannot support most marine life.
- Cause: Dead zones often occur as a result of nutrient pollution, primarily from agricultural runoff containing excess nitrogen and phosphorus, which leads to excessive algal growth. When these algae die and decompose, they consume oxygen, creating low-oxygen conditions that suffocate marine organisms such as fish, shrimp, and crabs.
- Impact: Dead zones can have significant ecological and economic impacts, including declines in fish populations, loss of biodiversity, and disruption of fisheries and coastal ecosystems.

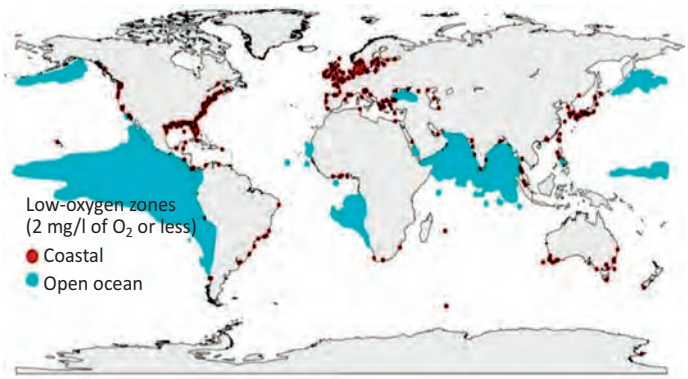


Fig. 9.5: Dead Zones in the World

- **Examples:**
  - **Gulf of Mexico Dead Zone:** One of the largest dead zones globally, it forms annually in the Gulf of Mexico off the coast of Louisiana and Texas. It is primarily caused by nutrient runoff from agricultural areas in the Mississippi River watershed.
  - **Chesapeake Bay Dead Zone:** The Chesapeake Bay, the largest estuary in the United States, experiences seasonal dead zones, particularly in the summer months. Excess nutrients from agricultural runoff, urban areas, and wastewater treatment plants contribute to the formation of dead zones, which affect aquatic species and commercial fisheries in the region.

Ocean Acidification

- Ocean acidification refers to the ongoing decrease in seawater pH and increase in acidity due to the absorption of carbon dioxide (CO_2) from the atmosphere.
- Cause: When CO_2 dissolves in seawater, it reacts with water to form carbonic acid, leading to a decrease in pH and changes in seawater chemistry.
- Impact: Ocean acidification can have detrimental effects on marine organisms, particularly those with calcium carbonate shells or skeletons, such as corals, shellfish, and plankton.
- It can impair their ability to build and maintain their calcium carbonate structures, leading to weakened shells, reduced growth rates, and increased vulnerability to predation and environmental stressors.
- Ocean acidification also has broader ecosystem impacts, affecting food webs, biodiversity, and ecosystem functioning.

Oil Spill

- An oil spill occurs when liquid petroleum hydrocarbons are released into the environment, typically from accidents involving oil tankers, offshore drilling platforms, pipelines, or storage facilities.
- Oil spills can have devastating effects on marine ecosystems, wildlife, and coastal communities.
- Oil can coat the surface of the water, forming slicks that harm marine birds, mammals, and fish by reducing their ability to regulate body temperature, impairing their buoyancy and ability to fly or swim, and causing skin and respiratory problems.
- Oil spills can also contaminate coastal habitats, including beaches, marshes, and coral reefs, and have long-term ecological and economic consequences, including loss of habitat, reduced fishery yields, and impacts on tourism and recreation.

Marine Debris in Ocean

- Trash and other debris in the ocean, collectively known as marine debris, refer to human-made materials that are discarded or abandoned in marine environments.
- Marine debris can include plastics, glass, metal, rubber, paper, and other materials, originating from sources such as coastal cities, fishing vessels, shipping activities, and offshore platforms.
- Marine debris can harm marine life through ingestion, entanglement, and habitat degradation, leading to injuries, suffocation, starvation, and death. It can also degrade coastal and marine habitats, transport invasive species, and pose risks to human health and safety.
- Efforts to address marine debris include prevention measures, cleanup and removal initiatives, public education and awareness campaigns, and policy and regulatory frameworks aimed at reducing plastic pollution and promoting sustainable waste management practices.

Microplastics

- Microplastics are tiny plastic particles that measure less than 5 millimeters in length.
- They can originate from various sources, including the breakdown of larger plastic debris, industrial processes, and the shedding of microfibers from synthetic textiles.
- These particles are pervasive in the environment and can be found in oceans, rivers, soil, and even in the air.
- Microplastics pose serious threats to marine life, ecosystems, and potentially human health as they can be ingested by organisms and enter the food chain.

Causes

- **Plastic Pollution:** The primary source of microplastics is the fragmentation of larger plastic items like bottles, bags, and packaging, through mechanical and chemical processes in the environment.
- **Microbeads:** Microbeads, tiny plastic particles used in personal care products like exfoliating scrubs and toothpaste, can directly enter water bodies through wastewater treatment plants.
- **Synthetic Fibres:** Synthetic fibres shed from clothing during washing contribute significantly to microplastic pollution in rivers and oceans.

- **Industrial Processes:** Plastic pellets used as raw materials in manufacturing processes can spill into the environment during production, transportation, and handling, contributing to microplastic pollution.

Impacts of Microplastics

- **Environmental Pollution:** Microplastics accumulate in the environment, including oceans, rivers, soil, and air, leading to widespread pollution.
- **Harm to Marine Life:** Marine animals often mistake microplastics for food, leading to ingestion. This can cause physical harm, internal blockages, and disrupt feeding behaviors, ultimately threatening marine biodiversity.
- **Bioaccumulation:** Microplastics can accumulate in the tissues of organisms over time, leading to higher concentrations as they move up the food chain. This poses risks to predators, including humans, who consume seafood contaminated with microplastics.
- **Toxic Chemical Transfer:** Microplastics can absorb and release harmful chemicals, such as persistent organic pollutants (POPs) and heavy metals. These chemicals can leach into the environment or be transferred to organisms upon ingestion of microplastics, potentially causing toxic effects.
- **Ecosystem Disruption:** Microplastics can disrupt marine ecosystems by altering nutrient cycles, reducing water quality, and promoting the spread of invasive species.
- **Economic Costs:** Microplastic pollution imposes economic costs through damage to ecosystems, fisheries, tourism, and public health, as well as the costs of cleanup and mitigation efforts.
- **Invasive Alien Species:** Plastics can act as vectors for marine species, helping them to disperse beyond their natural ecological area. This process is called Plastic Rafting.
  - **Example:** The Smithsonian Environmental Research Center in 2017 counted 289 Japanese marine species that were carried to distant shores after the 2011 tsunami, including sea snails, sea anemones and isopods, a type of crustacean.

Measures to Address Microplastic Pollution

- **Regulatory Bans:** Several countries and regions have implemented bans or restrictions on the use of microbeads in personal care products to reduce their contribution to microplastic pollution.
  - **Example:** India banned the manufacture, distribution, stocking, sale and use of selected 19 single-use plastic items with effect from July 1, 2022.
- **Wastewater Treatment:** Improved wastewater treatment processes are being developed to capture and remove microplastics before discharge into water bodies.
- **Innovative Technologies:** Research and development efforts focus on innovative technologies to capture and remove microplastics from the environment, such as filtration systems and floating barriers.
  - **Example:** The use of plastic waste in the construction of road protects the environment from adverse impact of waste plastic. India constructed more than 703 km of highways using plastic waste.
- **Product Design:** Encouraging the design of products with fewer microplastic components and promoting the use of biodegradable or natural alternatives in manufacturing processes.

SOIL POLLUTION

Soil Pollution refers to the contamination of soil with harmful substances, chemicals, or waste materials, which adversely affect its quality and fertility.

Soil Pollution Status

Global Soil Pollution

- **One-third** of the world's soils are estimated to be **degraded**, impacting over **3.2 billion people** globally.
- **Economic impact:** Costs the global economy an estimated **$8.5 trillion** annually.
- **Salinization:** Affects over 1 billion hectares of land globally, reducing its productivity and impacting agricultural livelihoods.
- **Soil erosion:** Estimated that over 24 billion tonnes of topsoil are lost annually due to erosion, primarily caused by unsustainable agricultural practices and deforestation.
- **Extinction risk:** Estimated that one-third of all soil organisms are at risk of extinction due to soil degradation.
- **Agricultural land:** Around 34% of all agricultural land is moderately or severely degraded.
- **Forests:** Around 20% of the world's forest area is affected by soil degradation.

Soil Pollution in India

- Some 97.85 million hectares **(29.7%) of India's total geographical area (TGA)** of 328.72 mha underwent land degradation during 2018-19. (Desertification and Land Degradation Atlas)
- The National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) estimates that **146.8 million hectares** of land in India are degraded.
- The **national average soil loss** in India is **15.59 tonnes/hectare/year.**
- A 2021 report by the Centre for Science and Environment (CSE) warns of alarming levels of nitrogen pollution in Indian soil and water due to excessive fertilizer use.

Causes of Soil Pollution

- **Industrial activities:** Release of toxic chemicals and heavy metals from industries.
  - Chemical manufacturing plants often release pollutants such as heavy metals (lead, mercury, cadmium) and organic compounds (like benzene, toluene) into the soil.
  - **Example:** Minamata disease outbreak in Japan was caused by the release of methylmercury from a chemical plant, contaminating soil and water, leading to severe health issues.
- **Agricultural practices:** Overuse of fertilizers, pesticides, and herbicides.
  - Excessive use of chemical fertilizers and pesticides has led to soil degradation and contamination.
  - **Example:** Punjab, known as the "Granary of India," has faced soil pollution due to intensive farming practices, particularly the Green Revolution.
- **Improper waste disposal:** Dumping of household, industrial, and hazardous waste.
  - Over the years, it has caused significant soil pollution and environmental degradation due to the accumulation of untreated waste, leachate seepage, and methane emissions, impacting nearby communities and ecosystems.
  - **Example:** The dumping of municipal solid waste in open landfills is a widespread issue in India. The Ghazipur landfill in Delhi is one of the largest and oldest dumping sites in the country.
- **Mining activities:** The extraction of minerals leads to soil degradation and contamination.
  - The release of radioactive waste into the environment has raised concerns about soil pollution and its potential health effects on local communities.
  - **Example:** The Jaduguda uranium mine in Jharkhand is one of India's oldest and largest uranium mines. Mining operations, including the extraction and processing of uranium ore, have led to soil contamination with heavy metals and radioactive elements.
- **Urbanization:** Construction activities, roadways, and urban runoff contribute to soil pollution.
  - Rapid urbanization and industrialization have led to soil pollution in many Indian cities. The discharge of untreated industrial effluents containing heavy metals and chemicals has polluted the soil and water bodies, posing health risks to residents.
  - **Example:** Kolkata, formerly known for its tanneries and leather industries, has faced soil contamination due to improper waste disposal practices and industrial pollution.

Harmful Effects of Soil Pollution

- **Reduced soil fertility:** Harmful chemicals disrupt nutrient balance, affecting plant growth. The Green Revolution, which aimed at increasing agricultural productivity, resulted in the depletion of organic matter and essential nutrients in the soil.
  - **Example:** In parts of Punjab and Haryana, excessive use of chemical fertilizers and pesticides has led to soil degradation and reduced fertility.
- **Contamination of the food chain:** Toxic substances enter plants, animals, and humans through food. Studies have found high levels of heavy metals like lead, cadmium, and arsenic in food crops grown in contaminated soil.
  - **Example:** In regions with industrial activities and improper waste disposal, such as the Kasargod district in Kerala, crops like rice and vegetables have been found to contain elevated levels of heavy metals.
- **Water pollution:** Contaminants leach into groundwater, rivers, and lakes, affecting water quality. The presence of agricultural runoff and untreated industrial effluents contaminates water sources in many parts of India.
  - **Example:** The Yamuna River receives large quantities of pollutants from agricultural fields, urban runoff, and industrial discharge. As a result, contaminants from the soil, including pesticides, heavy metals, and nitrates, leach into the river, degrading water quality and posing risks to human health and aquatic ecosystems.
- **Health hazards:** Exposure to contaminated soil can lead to respiratory issues, skin diseases, and cancers.In areas with high soil pollution, such as regions surrounding industrial sites or landfills, residents often suffer from various health issues.
  - **Example:** In Bichhri village, Rajasthan, where soil and groundwater are contaminated with toxic heavy metals from nearby industrial waste, villagers have reported cases of skin diseases, respiratory problems, and higher incidence of cancer.
- **Ecosystem disruption:** Soil pollution can harm soil organisms, leading to biodiversity loss and ecosystem imbalance. Soil pollution can disrupt soil ecosystems and lead to biodiversity loss.
  - **Example:** In the Western Ghats region of India, extensive deforestation, agricultural expansion, and soil degradation have threatened the habitat of various endemic species.

Measures to Control Soil Pollution

Global Initiatives

- **International Agreements and Protocols:** Participation in international agreements and protocols such as the Stockholm Convention on Persistent Organic Pollutants (POPs) and the Minamata Convention on Mercury to address global soil pollution issues and promote cooperation among nations.

- **Sustainable agricultural practices:** Sustainable agricultural practices maximize productivity and profitability while minimizing negative impacts on the environment, conserving natural resources, and enhancing social equity and economic viability.
  - **Examples:** Crop rotation: In Brazil, adopting crop rotation practices in sugarcane cultivation has helped reduce reliance on herbicides, leading to improved soil health and reduced soil contamination.
- **Soil Remediation Technologies:** Countries have implemented soil remediation projects in contaminated sites through innovative technologies such as phytoremediation and soil vapor extraction.
  - **Examples:** The Superfund program by the United States Environmental Protection Agency (EPA) utilizes these technologies to clean up hazardous waste sites and restore soil quality.
  - **Genetic engineering** enables the creation of microorganisms with enhanced abilities to break down pollutants, aiding in the cleanup of contaminated environments. For instance, engineered bacteria can be designed to metabolize oil spills more efficiently, facilitating quicker and more effective bioremediation processes.
- **Brownfield Redevelopment Programs:** The European Union's Brownfield Redevelopment Initiative supports the revitalization of contaminated industrial sites across Europe through soil remediation and sustainable land use planning.
  - **Example:** Projects like the Thames Gateway in the United Kingdom aim to transform former industrial areas into vibrant urban spaces while addressing soil pollution issues.
- **Soil Monitoring Networks:**
  - **Example:** The Global Soil Partnership (GSP), led by the Food and Agriculture Organization (FAO) of the United Nations, coordinates soil monitoring efforts worldwide through initiatives like the Global Soil Information System (GLOSIS).

India's Initiatives

- **Soil Health Card Scheme:** This government initiative provides farmers with soil health assessments and recommendations for appropriate fertilizers and amendments based on specific soil conditions. This aims to promote targeted nutrient management and reduce unnecessary chemical inputs.
- **National Mission on Sustainable Agriculture (NMSA):** This mission promotes various practices like organic farming, bio-fertilizers, and vermicomposting, encouraging sustainable soil management practices.
- **Campaigns for Soil Health:** Awareness campaigns foster a better understanding of the importance of soil health and encourage the adoption of sustainable soil management practices.
  - **Example:** National Campaign on Soil Health Management (Nutrient Use Efficiency and SOC Management) based on LiFE (Lifestyle For Environment) was organized by ICAR and Indian Institute of Soil Science in Bhopal.
- **Regulations and amendments:** The Environment Protection Act (1986) and related amendments regulate the use and disposal of hazardous waste, industrial effluents, and bio-medical waste, aiming to minimize soil contamination from these sources.

Challenges in Measures Taken to Control Soil Pollution

- **Contaminant Persistence:** Soil pollutants can persist in the environment for extended periods, posing long-term risks to ecosystems and human health.
  - **Example:** In India, soil pollution from heavy metals like lead and chromium in industrial areas such as Bhiwandi in Maharashtra persists despite remediation efforts, affecting soil quality and agricultural productivity.
- **Limited Remediation Technologies:** Effective remediation technologies for soil pollution are limited, especially for complex mixtures of contaminants.
  - **Example:** Globally, remediation of soil contaminated with POPs like polychlorinated biphenyls (PCBs) remains a significant challenge due to the persistence and widespread distribution of these pollutants in soil and sediment.
- **Lack of Awareness and Monitoring:** Limited awareness about soil pollution and inadequate monitoring infrastructure hamper early detection and intervention.
  - **Example:** In areas like Unnao, Uttar Pradesh, where illegal disposal of toxic waste occurred, soil contamination was discovered only after public outcry.
- **Fragmented Regulatory Frameworks:** Regulatory frameworks for soil pollution control may be fragmented or insufficiently enforced, leading to gaps in pollution prevention and remediation efforts.
  - **Example:** Inadequate regulation of pesticide use has led to soil contamination in agricultural areas of Palakkad in Kerala.
- **Land Use Conflicts:** In urban areas worldwide, soil contamination resulting from industrial activities often conflicts with urban redevelopment plans.
  - **Example:** Industrial pollution of soil in areas like Mahul in Mumbai hinders efforts to reclaim land for urban development.

Way Forward

- **Soil remediation:** Techniques like phytoremediation, bioremediation, and soil washing can help remove contaminants.

- **Example:** Nadia district of West Bengal is highly contaminated with arsenic (As). Phytoremediation of arsenic at Nadia was done using Vetiver grass.

- **Waste management:** Proper disposal and recycling of waste materials to prevent soil contamination.
  - **Example:** The waste-to-energy plant in Okhla, Delhi, converts a portion of municipal solid waste into electricity, reducing the amount of waste sent to landfills. This initiative not only helps in waste management but also prevents soil contamination from untreated waste disposal.
- **Sustainable agricultural practices:** Reduced chemical use, crop rotation, and organic farming methods.
  - **Example:** The Zero Budget Natural Farming (ZBNF) movement, initiated by agriculturist Subhash Palekar, advocates for chemical-free farming practices. Farmers across states like Andhra Pradesh and Karnataka have adopted ZBNF techniques, including the use of natural fertilizers and pest repellents, contributing to soil conservation and pollution prevention.
- **Environmental regulations:** Implementing and enforcing laws to control pollution from industries and waste disposal.
  - **Example:** The Environment (Protection) Act, 1986, and other legislation provide a legal framework for controlling pollution from industries, prescribing standards for emissions and waste disposal, and facilitating environmental impact assessments to prevent soil pollution.
- **Public awareness and education:** Promoting responsible behavior and eco-friendly practices to prevent soil pollution.
  - **Example:** The Centre for Science and Environment (CSE), a non-profit organization based in India, conducts awareness campaigns and educational programs on environmental issues, including soil pollution. Through workshops, seminars, and publications, CSE aims to raise awareness among the public, policymakers, and stakeholders about the importance of soil conservation and pollution prevention.

NOISE POLLUTION

- Noise pollution refers to excessive, unpleasant, or harmful levels of noise in the environment that disrupt normal activities, affect human health, and disturb wildlife.
- The World Health Organization (WHO) defines noise above 65 decibels (dB) as noise pollution.
- To be precise, noise becomes harmful when it exceeds 75 decibels (dB) and is painful above 120 dB.

Noise Pollution Status

Global Noise Pollution

- **WHO estimates:** Over 1 billion people worldwide are exposed to chronic noise levels exceeding safe limits (65 dB).
- Nearly 466 million people globally are affected by moderate to severe hearing loss, with noise pollution contributing significantly.

Noise Pollution in India

- **Road traffic** is a major contributor pf noise pollution in India, with car horns and bus horns exceeding **100 dB.**
- **Construction activities** that use drilling and machinery have noise levels that reach **110 dB.**
- Estimated **63 million** Indians suffer from moderate to severe hearing loss, likely linked to noise pollution.
- A 2023 survey by **Earth5R** found noise levels in Indian cities nearly 50% higher than permissible limits.
  - Cities like Delhi, Kolkata, and Mumbai consistently exceed safe noise levels.

Causes of Noise Pollution

- **Industrial activities:** Factories, machinery, and equipment produce significant noise levels.
- **Transportation:** Vehicles, airplanes, trains, and ships generate noise during operation.
- **Construction:** Construction sites involve heavy machinery, drilling, and other activities that create high levels of noise.
- **Urbanization:** Dense urban areas experience increased noise due to population density, traffic, and construction.
- **Recreational activities:** Events like concerts, sporting events, and festivals can produce loud noise levels.

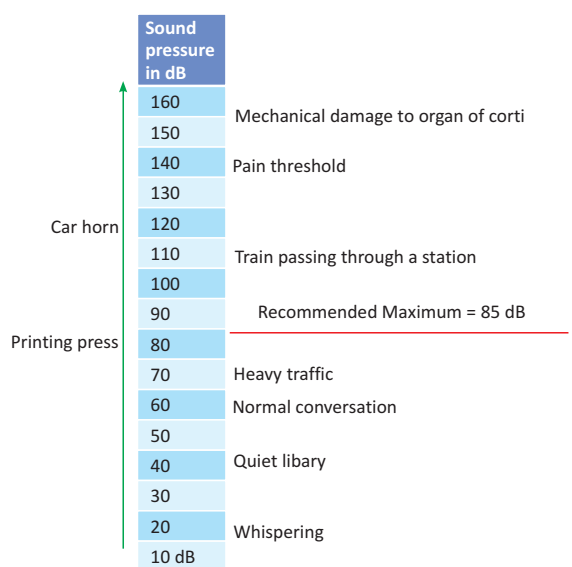


Fig. 9.6: General Noise Levels

Noise Levels

- Noise level is measured in decibels (dB). The louder the noise, the higher the decibels. Decibels can be adjusted to human hearing.
- Noise level is thus described in decibels A (dBA). The effects of noise vary with the noise to which a person is exposed.
- Prolonged exposure to loud noises (85 dBA over eight hours a day for years) can lead to hearing loss.
- The body can also respond to lower noise levels: sleep can be disturbed by an outdoor noise of 40 dBA.

{The World Health Organization (WHO) recommends that noise exposure levels **should not exceed 70 dB** over a **24-hour period,** and **85 dB** over a **1-hour period** to avoid hearing impairment.}

Harmful Effects of Noise Pollution

- **Hearing loss:** Prolonged exposure to high noise levels can damage the delicate structures of the inner ear, leading to permanent hearing loss.
- **Sleep disturbances:** Loud noise can disrupt sleep patterns, leading to insomnia and fatigue.
- **Stress and anxiety:** Continuous exposure to noise can trigger stress responses, leading to anxiety, irritability, and decreased productivity.
- **Cardiovascular problems:** Chronic noise exposure has been linked to increased blood pressure, heart disease, and stroke risk.
- **Cognitive impairment:** Noise pollution can impair concentration, memory, and learning abilities, particularly in children.

Measures to Control Noise Pollution

Global Initiatives

- **Noise Barriers:** The construction of noise barriers along highways help mitigate traffic noise impacts on nearby communities.
  - **Example:** In the United States, the Federal Highway Administration (FHWA) oversees numerous noise barrier projects along the Interstate Highway System includes, such as the Long Island Expressway Noise Barrier in New York.
- **Vehicle Noise Regulations:** These regulations set noise limits for vehicle exhaust systems and require the use of sound-reducing technologies.
  - **Example:** The European Union (EU) has implemented the Euro 6 emission standards which mandate quieter vehicle designs to reduce traffic noise.
- **Urban Planning and Zoning Policies:** Urban centres have implemented strict land-use planning policies to separate noisy activities from noise-sensitive areas.
  - **Example:** Industrial zones in Singapore are strategically located away from residential neighborhoods to minimize residents' exposure to industrial noise pollution.
- **Green Spaces and Soundscaping:** Creation and preservation of green spaces, parks, and vegetative buffers in urban areas to act as natural noise barriers and provide acoustic insulation, contributing to overall noise reduction.

  {**Soundscapes** refer to the natural acoustic environment in addition to sounds that are created by humans.}
  - **Example:** The city of Oslo, Norway, has prioritized the creation of green spaces and soundscaping initiatives to reduce urban noise levels.
- **Quiet Urban Design and Architecture:** Incorporation of noise-reducing design principles and materials in urban infrastructure and buildings, such as acoustic insulation, double-glazed windows, and noise-absorbing facades, helps mitigate indoor noise levels.
  - **Example:** The Hardbrücke railway viaduct in Zurich is equipped with noise-absorbing barriers and soundproofing measures to minimize railway noise impacts on nearby residential areas.

India's Initiatives

- **Noise Pollution (Regulation and Control) Rules, 2000:** These rules provide guidelines and standards for controlling and regulating noise pollution across different areas, such as industrial zones, residential areas, and silence zones. The rules specify permissible noise levels for various activities and prescribe measures for noise control and mitigation.
- **The Environment (Protection) Act, 1986:** This legislation empowers the Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs) to take measures for preventing and controlling environmental pollution, including noise pollution. Under this act, authorities have the authority to enforce noise pollution regulations and take action against violators.
- **The Motor Vehicles Act, 1988:** This act includes provisions related to the regulation of vehicle noise emissions. It mandates the use of noise-reducing measures in vehicle design and imposes penalties for violations of noise emission standards.
- **Supreme Court Directives:** The Supreme Court of India has issued various directives and judgements to address noise pollution, including restrictions on the use of loudspeakers, firecrackers, and construction activities during specific times, especially during festivals and nighttime.
  - **Example:** The Supreme Court in July 2005 banned the use of loudspeakers and music systems between 10 pm to 6 am (except in cases of public emergencies) at public places citing serious effects of noise pollution on health of the people living in such areas.

- **State-Level Initiatives:** Several states have implemented additional measures and regulations to address noise pollution based on local needs and conditions.
  - **Example:** Mumbai has designated certain areas as silence zones, including hospitals, schools, and courts, where noise levels must not exceed prescribed limits.
- **Public Awareness Campaigns:** Government agencies, non-governmental organizations (NGOs), and civil society groups conduct public awareness campaigns to educate citizens about the adverse effects of noise pollution and encourage them to adopt measures for noise reduction and control.
  - **Example:** The "Horn Not Ok Please" campaign in Mumbai encourages drivers to refrain from unnecessary honking, thereby reducing noise pollution on the streets.

Challenges in Measures taken to Control Noise Pollution

- **Urbanization and Industrialization:** In rapidly developing regions like Southeast Asia, urbanization and industrial expansion outpace noise mitigation efforts.
  - **Example:** For example, in cities like Jakarta, Indonesia, rapid urban growth has led to mixed land-use zoning, with residential areas co-located with noisy industrial and commercial zones, resulting in high levels of noise pollution for residents.
- **Lack of Awareness and Compliance:** Many businesses in commercial areas operate machinery and equipment without adhering to noise regulations.
  - **Example:** Restaurants and entertainment venues like concerts often exceed permissible noise levels, leading to complaints from nearby residents and patrons.
- **Technological Limitations:** Retrofitting noise control measures in existing infrastructure, such as highways or railways, poses challenges.
  - **Example:** Installing noise barriers along busy highways or retrofitting older buildings with sound insulation can be costly and logistically complex, delaying implementation.
- **Social and Cultural Acceptance:** Efforts to reduce noise pollution, such as implementing nighttime construction bans, may face resistance from stakeholders who prioritize economic activity over noise reduction.
  - **Example:** In densely populated cities like New York City, the constant hum of urban life is often accepted as a part of living in a vibrant metropolis.

Way Forward

- **Implementing noise regulations:** Governments can enforce noise regulations and zoning laws to control noise levels in urban areas and near sensitive locations like schools and hospitals.
- **Noise barriers:** Constructing barriers along highways and railways can help reduce noise propagation into surrounding areas.
- **Noise reduction technologies:** Encouraging the use of quieter machinery, vehicles, and equipment through technological advancements and regulations.
- **Urban planning:** Designing cities with noise mitigation strategies in mind, such as green spaces and buffer zones between residential and industrial areas.
- **Public awareness and education:** Educating the public about the harmful effects of noise pollution and promoting behavioral changes to reduce noise emissions.

RADIOACTIVE POLLUTION

Radioactive Pollution refers to the presence of radioactive substances in the environment, that emit harmful radiation. These substances may come from various sources including nuclear power plants, mining and processing of radioactive materials, medical facilities, industrial processes, and nuclear accidents.

Radioactive Pollution Status

Global Radioactive Pollution

- **Total solid radioactive waste:** Approximately **392,000 tonnes of heavy metal (tHM)** generated since the first nuclear power plants began operating (IAEA estimate).
- **Spent nuclear fuel:** Represents the majority of waste, with about **265,000 tHM** not reprocessed (IAEA estimate).
- **High-level waste (HLW):** Represents a small fraction, with an estimated **29,000 m^3** of disposal volume globally (World Nuclear Association).

Radioactive Pollution in India

- **Annual generation:** Estimates suggest India generates around **4 tonnes** of radioactive waste per Gigawatt (GW) of nuclear power capacity annually.

Causes of Radioactive Pollution

- **Nuclear power plants:** Radioactive materials are used as fuel to generate electricity, and sometimes accidents or leaks can occur.
- Accidents like Three mile Island accident, Chernobyl accident and Fukushima Daiichi accident leave an area unfit for habitat for years and cause billions of dollar in clean up.
- **Nuclear weapons testing:** Detonating nuclear weapons releases radioactive fallout into the atmosphere.
- **Mining and processing of radioactive ores:** Activities such as uranium mining can release radioactive materials into the environment.

- **Medical facilities:** Radioactive materials are used in diagnostic and therapeutic procedures, and improper disposal can lead to pollution.
- **Industrial processes:** Some industrial activities involve the use of radioactive substances, leading to pollution if not properly managed.

Harmful Effects of Radioactive Pollution

- **Increased risk of cancer:** Exposure to radiation from radioactive pollutants can damage cells and increase the risk of various types of cancer.
- **Genetic mutations:** Radioactive pollution can cause mutations in DNA, leading to hereditary disorders and birth defects.
- **Environmental damage:** Radioactive pollution can contaminate soil, water, and air, harming ecosystems and wildlife.
- **Acute radiation sickness:** High levels of radiation exposure can cause symptoms such as nausea, vomiting, and organ failure.

Measures to Control Radioactive Pollution

Global Initiatives

- **Regulatory Frameworks:**
  - Countries around the world have established regulatory agencies and frameworks to monitor and control radioactive pollution. These agencies set standards, regulations, and guidelines for the use, storage, transportation, and disposal of radioactive materials.
- **Waste Management Practices:**
  - Advanced waste management practices, such as deep geological disposal and engineered containment facilities, are employed to safely store and dispose of radioactive waste. These practices aim to isolate radioactive materials from the environment and prevent contamination of soil, water, and air.
- **Radiation Monitoring Networks:**
  - Radiation monitoring networks are established to continuously monitor ambient radiation levels in the environment. These networks include monitoring stations, sensors, and surveillance programs that track radiation emissions from nuclear facilities, industrial sites, and natural sources.

India's Initiatives

- **Atomic Energy Regulatory Board (AERB):**
  - India's Atomic Energy Regulatory Board (AERB) regulates and monitors nuclear and radiation-related activities to ensure safety and prevent radioactive pollution. The AERB sets standards, conducts inspections, and licenses nuclear facilities to minimize the risk of radioactive contamination.
- **Nuclear Waste Management:**
  - India has developed strategies for the safe management and disposal of radioactive waste. Facilities such as the Waste Immobilization Plant (WIP) at Tarapur and the Waste Management Division of the Bhabha Atomic Research Centre (BARC) are responsible for treating and storing radioactive waste.
- **Environmental Monitoring:**
  - Environmental monitoring programs, conducted by organizations such as the Environmental Survey Laboratory (ESL) and the National Environmental Engineering Research Institute (NEERI), assess ambient radiation levels and monitor potential sources of radioactive pollution. These programs help identify contamination hotspots and guide remediation efforts.

Challenges in Measures taken to Control Radioactive Pollution

- **Complexity of Nuclear Waste Management:** Safe disposal of radioactive waste requires long-term containment solutions, posing technical and logistical challenges.
  - **Example:** Construction of deep geological repositories faces technical hurdles like ensuring containment integrity and preventing groundwater contamination.
- **Regulatory Compliance and Enforcement:** Ensuring adherence to radiation safety standards across nuclear facilities is difficult due to inadequate oversight in black.
  - **Example:** The Fukushima Daiichi nuclear disaster in Japan highlighted shortcomings in regulatory oversight and emergency preparedness, leading to widespread contamination of the environment with radioactive materials and long-term health risks for affected populations.
- **International Cooperation and Diplomacy:** Geopolitical tensions and regulatory differences impede international collaboration on radioactive pollution.
  - **Example:** Disputes over nuclear proliferation strain diplomatic relations, hindering agreements on safe waste management.
- **Emerging Risks and Technological Advances:** Advancements in nuclear technology introduce new safety concerns and waste management challenges.
  - **Example:** Increasing use of radioactive isotopes in medicine raises concerns about safe handling and disposal practices.

Way Forward

- **Strict regulations and monitoring:** Governments should enforce strict regulations on the use, storage, and disposal of radioactive materials, along with regular monitoring of pollution levels.

- **Cleanup and remediation:** Efforts should be made to clean up contaminated sites and rehabilitate affected areas to minimize exposure to radioactive pollutants.
- **Public awareness and education:** Educating the public about the risks of radioactive pollution and promoting responsible practices can help prevent accidents and minimize exposure.
- **Development of alternative energy sources:** Investing in renewable energy sources such as solar and wind power can reduce reliance on nuclear energy, thereby decreasing the production of radioactive waste.
- **International cooperation:** Given the transboundary nature of radioactive pollution, international cooperation is crucial to address issues such as nuclear accidents and the illegal trafficking of radioactive materials.

BIOLOGICAL POLLUTION

Biological Pollution, also known as bio-pollution or biological contamination, refers to the introduction of harmful organisms or substances into the environment, disrupting natural ecosystems and causing adverse effects on human health and the environment.

Biological Pollution Status

Global Biological Pollution

- After habitat loss, **invasive species** are the second greatest threat to biodiversity. They are known to cost the global economy an estimated **US$1.4 trillion every year.**
- Antimicrobial resistance (AMR) is one of the top global public health and development threats.
  - It is estimated that bacterial **AMR** was **directly responsible for 1.27 million global deaths** in 2019 and contributed to **4.95 million deaths.**
- The **World Bank** estimates that AMR could result in **US$ 1 trillion** additional healthcare costs by **2050**, and **US$ 1 trillion to US$ 3.4 trillion gross domestic product (GDP) losses per year by 2030.**

Biological Pollution in India

- The **Fall Armyworm**, an invasive pest, caused estimated losses of **₹50,000 crore** to Indian agriculture between **2018** and **2020.**
- According to the **Indian Council of Agricultural Research (ICAR), locust swarms** caused an estimated loss of **many crores** to crops in Rajasthan alone in **2020.**
- A 2023 study published in the Journal of Applied Ecology suggests over **2,000 invasive alien species** in India, with **158,000 plots** across **358,000 sq km** showing invasion by alien species.
- A 2022 study estimated that **10 invasive alien species cost the Indian economy $127.3 billion (₹8.3 trillion) in the last 60 years.**
- This study suggests India is the **second-highest** country globally in terms **of invasive alien species related costs**, highlighting the significant economic burden.
- The aforementioned 2023 study found that **66%** of India's natural systems are threatened by invasive plant species.

Causes of Biological Pollution

- **Invasive Alien Species:** Non-native species introduced into new habitats can outcompete native species, disrupt ecosystems, and cause ecological imbalances.
- **Pathogens:** Disease-causing microorganisms such as bacteria, viruses, fungi, and parasites can contaminate water, soil, and air, leading to the spread of infectious diseases.
- **Agricultural Practices:** The use of pesticides, herbicides, and fertilizers can lead to pollution of soil and water bodies, affecting biodiversity and human health.
- **Domestic and Industrial Waste:** Improper disposal of organic waste, sewage, and wastewater can result in the release of pathogens and nutrients, leading to water pollution and eutrophication.
- **Genetic Pollution:** Cross-breeding between genetically modified organisms (GMOs) and wild species can result in the transfer of modified genes into natural populations, potentially altering genetic diversity.

Harmful Effects of Biological Pollution

- **Spread of Diseases:** Biological pollutants can cause infectious diseases in humans, animals, and plants, leading to illness, mortality, and economic losses.
- **Ecological Disruption:** Invasive species can outcompete native species, disrupt food chains, and alter habitat structure, leading to biodiversity loss and ecosystem degradation.
- **Water and Soil Pollution:** Pathogens and nutrients from agricultural and urban runoff can contaminate water bodies and soil, impairing water quality, and fertility.
- **Economic Impacts:** Biological pollution can result in reduced agricultural productivity, increased healthcare costs, damage to infrastructure, and loss of revenue from tourism and fisheries.

Measures to Control Biological Pollution

Global Initiatives

- **International Cooperation and Collaboration:**
  - **Example:** The Convention on Biological Diversity (CBD) encourages international cooperation to address biological pollution through mechanisms like Cartagena Protocol. Aichi targets and now Kunming- Montreal Global Biodiversity Framework contains targets to eradicate, eliminate, minimise or reduce Invasive Alien Species. Initiatives such as the Global Invasive Species Programme (GISP) facilitate collaboration between countries to share information, develop best practices, and coordinate efforts to combat invasive species on a global scale.
- **Research and Monitoring Programs:**
  - **Example:** The Global Invasive Species Database (GISD) maintained by the International Union for Conservation of Nature (IUCN) provides comprehensive information on invasive species worldwide. This database supports research, monitoring, and management efforts by compiling data on invasive species distributions, impacts, and control measures.
- **Community Engagement and Citizen Science:**
  - **Example:** Citizen science projects, such as iNaturalist and EDDMapS, engage volunteers in monitoring and reporting invasive species sightings. These initiatives empower communities to contribute data to scientific research and management efforts, enhancing early detection and response to invasive species.

India's Initiatives

- **Integrated Pest Management (IPM) Practices:** IPM approaches emphasize the use of ecologically sound strategies, such as biological control agents and cultural practices, to minimize reliance on chemical pesticides.
  - **Example:** The Indian Council of Agricultural Research (ICAR) promotes integrated pest management (IPM) practices to control invasive pests and pathogens in agriculture.
- **Invasive Species Eradication Campaigns:** These campaigns target control of invasive plants, by utilizing manual removal, biological control, and habitat restoration techniques.
  - **Example:** The Forest Department of Tamil Nadu, India, implements invasive species eradication campaigns against invasive plants like Lantana camara and Prosopis juliflora in protected areas such as the Nilgiri Biosphere Reserve.
- **Ecosystem Restoration and Rehabilitation Projects:** Restoration efforts focus on restoring native habitats and controlling invasive species to enhance ecosystem resilience and biodiversity conservation.
  - **Example:** The Ministry of Environment, Forest and Climate Change (MoEFCC) in India supports ecosystem restoration and rehabilitation projects to combat biological pollution.
- **National Biodiversity Action Plan:** The Indian government's National Biodiversity Authority (NBA) collaborates with state biodiversity boards to implement the National Biodiversity Action Plan (NBAP).
  - **Example:** Under NBAP, initiatives such as the National Initiative on Invasive Alien Species (NIIAS) focus on preventing the introduction and spread of invasive species.
- **Protected Area Management:**
  - **Example:** The Periyar Tiger Reserve in Kerala, India, implements stringent biosecurity measures to protect its biodiversity from invasive threats.
    - The reserve conducts regular monitoring and surveillance to detect and control invasive species, such as the removal of invasive plants like Lantana camara from sensitive habitats.

Challenges in Measures Taken to Control Biological Pollution

- **Globalization and Trade:** Global trade facilitates unintentional invasive species introduction. Inadequate biosecurity at borders exacerbates the problem.
  - **Example:** Brown marmorated stink bug introduced to the US via shipping containers from Asia.
- **Limited Resources and Capacity:** Insufficient funding and expertise hinder invasive species management, especially in developing countries.
  - **Example:** African nations struggle to manage invasive species like water hyacinth due to resource constraints.
- **Complexity of Ecosystems:** Ecosystem dynamics complicate invasive species prediction and mitigation.
  - **Example:** The introduction of the invasive Nile perch (Lates niloticus) into Lake Victoria led to the decline of native fish species and disrupted the lake's ecological balance.
- **Lack of Coordination and Collaboration:** Invasive species control requires coordination across sectors and jurisdictions.
  - **Example:** Fragmented regulatory frameworks in the US lead to inconsistent management approaches for invasive species.
- **Climate Change and Environmental Uncertainty:** Climate change alters invasive species distribution and impacts, challenging response efforts.
  - **Example:** Asian tiger mosquito expansion due to climate change increases the risk of vector-borne diseases.

Way Forward

- **Prevention:** Implementing measures to prevent the introduction and spread of invasive species, such as strict biosecurity measures and regulations on international trade.
- **Control Measures:** Implementing control methods, such as biological control agents, pesticides, and habitat restoration, to manage invasive species and reduce their impact on native ecosystems.
- **Waste Management:** Improving waste management practices, including proper disposal and treatment of sewage, agricultural runoff, and industrial waste, to minimize contamination of soil and water resources.
- **Public Awareness:** Educating the public about the risks of biological pollution and promoting sustainable practices to reduce pollution and protect biodiversity.
- **Policy and Regulation:** Enforcing regulations and policies to monitor and regulate the use of pesticides, GMOs, and other potential sources of biological pollution, to ensure environmental and public health protection. Coordination with other private sector, multilateral bodies to develop and follow strict custom standards from biological point of view.

LIGHT POLLUTION

Light Pollution refers to the excessive or misdirected artificial light that brightens the night sky and interferes with natural darkness. It is caused by the inappropriate or excessive use of artificial lighting.

Light Pollution Status

Global Light Pollution

- According to the **World Atlas on Night Sky Brightness** report, the majority of the world's population, over 80%, resides in areas where artificial light obscures the night sky, causing light pollution.
- Nearly **one-third** of people worldwide are **unable to see the Milky Way galaxy** due to light pollution.
- Moreover, regions covering **23%** of the world's land surfaces between 75°N and 60°S, i.e. **88%** of **Europe**, and almost **50%** of the **United States** experience nights affected by light pollution.
- Based on **Naked-Eye Limiting Magnitude (NELM) data** there has been a global average increase in the light pollution of **9.6%** (10.4% in North America) per year between **2011 and 2022.**
- **2023** revealed that terrestrial light pollution has been increasing at a faster rate of **10%** each year.

Light Pollution in India

- A study published in 2019 titled **"Artificial night sky brightness and its effects on human health and the environment in India"** revealed that India's night skies have become approximately **20% brighter** in the last decade.
- The research also indicates that **nearly 70%** of India's population resides under skies affected by light pollution, with major cities such as **Mumbai, New Delhi, and Kolkata** facing particularly severe levels of light pollution.

Causes of Light Pollution

- **Urbanization:** The expansion of urban areas leads to increased artificial lighting, resulting in skyglow, where the night sky becomes brighter than natural due to scattered light.
- **Outdoor Lighting Practices:** Poorly designed or excessive outdoor lighting fixtures contribute to light pollution by directing light upwards or emitting excessive glare.
- **Advertising and Street Lighting:** Brightly lit billboards, streetlights, and commercial signage contribute to light pollution when not properly shielded or regulated.
- **Industrial Activities:** Industrial facilities often employ high-intensity lighting for safety and security purposes, contributing to light pollution in surrounding areas.

Harmful Effects of Light Pollution

- **Disruption of Ecosystems:** Light pollution disrupts the behavior and habitats of nocturnal animals, affecting their feeding, mating, and migration patterns.
- **Health Impacts:** Exposure to artificial light at night can disrupt circadian rhythms and melatonin production, potentially leading to sleep disorders, increased risk of certain cancers, and other health issues.

  {**Circadian rhythms** are the physical, mental, and behavioral changes an organism experiences over a **24-hour cycle. Melatonin** is a hormone that your brain produces in response to darkness. It helps with the timing of our circadian rhythms (24-hour internal clock) and with sleep. Being exposed to **light** at night can **block melatonin production**}
- **Astronomical Interference:** Light pollution obscures the visibility of stars, planets, and other celestial objects, limiting astronomical observation and research.
- **Wasteful Energy Consumption:** Excessive outdoor lighting wastes energy and contributes to greenhouse gas emissions, increasing environmental impact and energy costs.

Marine Light Pollution

- Moonlight and starlight serve as important cues for marine organisms, and their glow can easily be overwhelmed by artificial light.
- LED lighting exacerbates the problem by producing light with shorter wavelengths that penetrate deeper into the water.
- Studies on marine light pollution found **shifts in hormonal cycles, interspecies behavior and reproduction.**
- **Example:**
  - Female sea turtles prefer quiet dark spots ashore to lay their eggs. To avoid light they end up not coming ashore at all.
  - Hatchlings head towards, inland lights instead of moonlight on the water and then die of dehydration or starvation.

Mitigation Measures

- **Darken skies:** Land-based Lights Out efforts – local, state and regional campaigns to darken skies to help migrating birds that are drawn to light at night – will benefit marine systems near coastal cities.
- **Red Light:** Red light doesn't penetrate as far into the water.
- **Coastal Barriers:** Coastal barriers help in shielding the coastline from artificial light.

Measures to Control Light Pollution

Global Initiatives

- **Lighting Design Standards:** The International Dark-Sky Association (IDA) promotes the adoption of dark-sky-friendly lighting design principles worldwide.
  - **Example:** Cities like Tucson, Arizona, in the United States, have implemented outdoor lighting ordinances based on IDA guidelines to reduce light pollution and preserve the night sky.
- **Smart Lighting Technologies:** These technologies help minimize light pollution by ensuring that illumination is only provided when and where needed.
  - **Example:** Cities such as Barcelona, Spain, have deployed smart lighting systems equipped with sensors and controls to adjust brightness levels based on real-time conditions.
- **Protected Areas and Dark Sky Reserves:** Designation of protected areas and dark sky reserves prohibit excessive outdoor lighting within the reserve boundaries to preserve the natural beauty and cultural significance of the night sky.
  - **Example:** The UNESCO World Heritage Site of Wadi Rum in Jordan is designated as a Dark Sky Reserve to protect its pristine night skies from light pollution.

India's initiatives

- **Urban Planning and Lighting Regulations:** The Indian Green Building Council (IGBC) sets guidelines for sustainable lighting in urban development projects.
  - **Example:** For instance, the IGBC's Green Cities Rating System encourages the use of energy-efficient lighting and dark-sky-friendly fixtures in urban infrastructure.
- **Public Awareness Campaigns:** These campaigns aim to educate communities, policymakers, and stakeholders about responsible outdoor lighting practices.
  - **Example:** The Indian Astronomical Observatory (IAO) conducts outreach programs and star parties to raise public awareness about the impacts of light pollution and the importance of preserving dark skies.
- **Policy Interventions:**
  - **Example:** The MoEFCC's National Clean Air Programme (NCAP) includes provisions for addressing light pollution as part of air quality management efforts.
  - In National parks and sanctuaries their are restrictions on use of artificial lights at night.
  - Proposal to set up Dark Sky Reserve in Hanle, Ladakh to boost astro tourism.

Challenges in Measures Taken to Control Light Pollution

- **Lack of Awareness:** Many are unaware of light pollution's impacts on ecosystems, health, and astronomy, hindering effective mitigation efforts.
- **Urbanization and Development:** Rapid urbanization leads to increased artificial light sources, challenging dark sky preservation.
  - **Example:** The Night Sky Brightness Atlas developed by the Light Pollution Science and Technology Institute indicates that urban areas experience higher levels of light pollution compared to rural regions, with densely populated cities such as New York and Tokyo exhibiting extensive light pollution due to urbanization and development.
- **Technological Advancements:** Widespread use of energy-efficient LED lights contributes to light pollution if improperly installed or shielded.
  - **Example:** Studies have demonstrated that improperly shielded LED streetlights can emit more blue-rich light, increasing skyglow and contributing to light pollution.

Skyglow

- Skyglow refers to the **brightening of the night sky** over inhabited areas, caused by **artificial sources** of light such as **streetlights, buildings, and industrial facilities.**

- It results from **light pollution,** which **scatters** and **reflects** off **particles** and **gases** in the atmosphere, creating a **luminous glow** that obscures the view of stars and celestial objects.
- This phenomenon is particularly noticeable in **urban** and **suburban areas,** where high concentrations of artificial light sources illuminate the night sky, even in the absence of direct sources of light.
- **Impacts:** Skyglow not only **obscures the natural beauty of the night sky** but also has ecological and health implications. It **disrupts** the behavior and habitats of nocturnal animals, affects **human circadian rhythms** and **sleep patterns,** and contributes to **energy waste and environmental degradation.**
- **Mitigation measures:** Efforts to mitigate skyglow involve implementing **outdoor lighting policies and regulations,** promoting the use of **energy-efficient lighting technologies,** such as **fully shielded fixtures** and **warm-colored LEDs,** and raising **awareness** about the impacts of light pollution on ecosystems, human health, and astronomical observations.

Fig. 9.7: Skyglow Intensity across Landscape

- **Economic Considerations:** Retrofitting lighting infrastructure for dark-sky-friendly solutions is costly, impeding investments.
  - **Example:** The city of Los Angeles estimated the cost of retrofitting streetlights with fully shielded fixtures to reduce light pollution at approximately $100 million.
- **Regulatory Frameworks:** Inconsistent regulations and poor enforcement undermine mitigation efforts.
  - **Example:** Inadequate enforcement of outdoor lighting regulations is evident in cities like Mumbai, where non-compliant lighting fixtures contribute to excessive light pollution.
- **Cultural and Social Norms:** Varying cultural attitudes towards brightly lit environments pose challenges in promoting dark-sky-friendly practices.
  - **Example:** In regions like the Gulf Cooperation Council (GCC) countries, brightly lit urban landscapes are synonymous with prosperity and modernization.
    - The cultural norm of showcasing vibrant cityscapes at night poses challenges in promoting dark-sky-friendly lighting practices, despite growing awareness of light pollution's impacts.

Way Forward

- **Proper Lighting Design:** Utilizing shielded and downward-facing fixtures, selecting lower-intensity bulbs, and employing motion sensors and timers can reduce light pollution while maintaining safety and visibility.
- **Lighting Regulations:** Implementing and enforcing regulations and guidelines for outdoor lighting practices, such as limiting brightness, controlling light trespass, and minimizing glare.
- **Public Awareness and Education:** Raising awareness about the impacts of light pollution and promoting responsible lighting practices among businesses, municipalities, and individuals.
- **Preserving Dark Sky Areas:** Establishing and protecting dark sky reserves and designated areas with minimal artificial light to preserve natural darkness and support astronomical research and tourism.

Dark Sky Reserve

- A **Dark Sky Reserve** is a designated area that aims to preserve and protect the quality of its night skies by minimising light pollution. Dark Sky Reserves are typically located in areas with exceptional natural darkness and starry skies.
- The establishment of Dark Sky Reserves is a designation given by the International Dark-Sky Association (IDA).
- And Hanle, with less than 1000 people living in the village, is the perfect area.
- The Hanle Observatory, also known as the Indian Astronomical Observatory, is a dark sky reserve.

Hanle Observatory

- The Hanle Observatory, also known as the Indian Astronomical Observatory, is located in Hanle village, at an altitude of approximately 4,500 metres (14,764 feet) above sea level.
- The Hanle region is known for its exceptionally clear skies and low light pollution, making it an excellent location for stargazing and astronomical observations. The absence of significant light sources in the surrounding area contributes to the relatively dark skies in Hanle.

Tackling light pollution requires a holistic approach that balances the need for illumination with the preservation of darkness. Addressing light pollution requires concerted efforts at various levels, including urban planning, lighting design, policy interventions, public awareness campaigns, and technological innovation.

Implementing measures such as the use of energy-efficient lighting, shielded fixtures, and motion sensors can help reduce light pollution while promoting energy conservation and cost savings. Moreover, the designation of dark sky reserves and the enforcement of light pollution regulations can safeguard natural habitats and preserve the cultural and scientific value of the night sky.

THERMAL POLLUTION

Thermal Pollution refers to the elevation of water temperatures in natural water bodies, such as rivers, lakes, and oceans, due to human activities. It occurs when industrial processes, power plants, and other sources discharge heated water or effluent into water bodies, altering their temperature regimes and thermal characteristics.

Thermal Pollution Status

Global Thermal Pollution of Rivers From Thermoelectric Power Plants

- Globally, **over 46%** of the **thermal emissions** into rivers are due to **coal-fuelled power plants** and almost **33%** due to **nuclear power plants.**
- The countries like **USA, China and France** have the highest combined rates of riverine **thermal emissions**, occupying shares of **26%, 16%, and 12%** of the global thermal emission rate, respectively

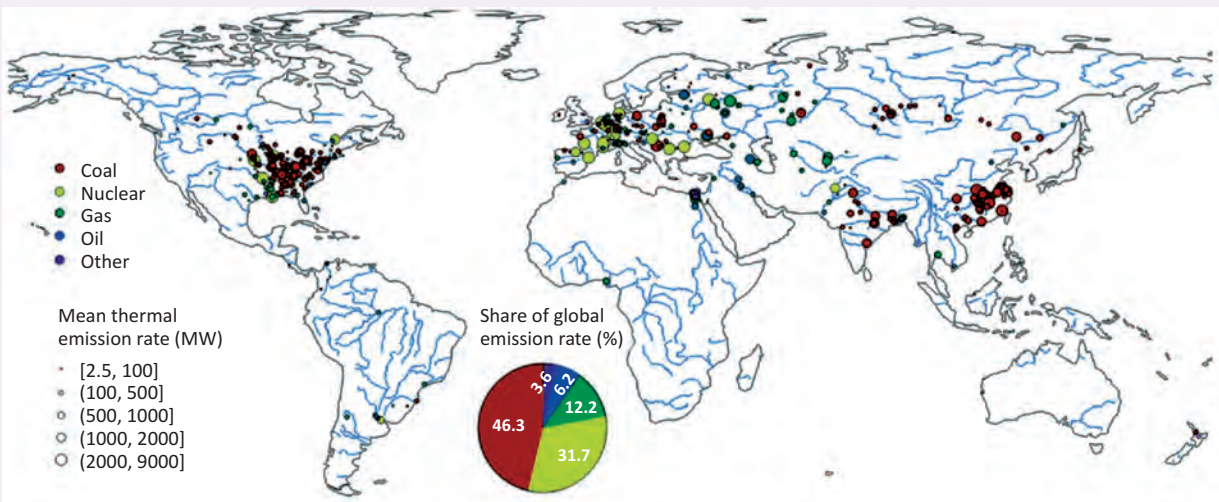


Fig. 9.8: Global Thermal Pollution

Thermal Pollution in India

- **Thermal Power Plants:** According to a report by the Centre for Science and Environment (CSE), thermal power plants are a major source of thermal pollution in India, with many plants exceeding permissible temperature limits for discharged water.
  - **Example:** The **Badarpur Thermal Power Station in Delhi** releases heated water into the Yamuna River, raising water temperatures and impacting aquatic ecosystems.
- **Industrial Discharges:** According to the Central Pollution Control Board (CPCB), industrial effluents contribute to elevated water temperatures in rivers like the Narmada, affecting aquatic life and water quality.
  - **Example:** The industrial hub of **Ankleshwar** in **Gujarat** is known for its high concentration of chemical and manufacturing industries. These industries discharge heated water containing pollutants into the nearby **Narmada River**, leading to thermal pollution and water quality degradation.
- **Coal Mines and Mining Activities:** Mining activities, including coal extraction, contribute to thermal pollution in water bodies near mining sites. The discharge of mine water containing elevated temperatures and pollutants into rivers and streams impacts water quality and aquatic habitats.
  - **Example:** Reports from environmental organizations highlight the impact of coal mining on thermal pollution in rivers like the **Damodar** in **Jharkhand** and **West Bengal,** where coal mines are prevalent.

Causes of Thermal Pollution

- Industrial Activities: Industries such as power plants, manufacturing facilities, and refineries often use water for cooling purposes in their operations. When this heated water is discharged back into water bodies like rivers or lakes, it raises the water temperature, contributing to thermal pollution.

- **Power Generation:** Power plants, both nuclear and conventional, require large amounts of water for cooling purposes. The heated water used for cooling is then released back into water bodies, leading to thermal pollution.
- **Urbanization:** Urban areas with increased concrete surfaces and reduced vegetation tend to absorb more heat, leading to higher temperatures in nearby water bodies. Additionally, urban runoff, which carries heat-absorbing materials such as asphalt and concrete, can contribute to thermal pollution.
- **Deforestation:** Removal of trees and vegetation along riverbanks and water bodies reduces shading and increases solar radiation absorption, leading to elevated water temperatures.

Harmful Effects of Thermal Pollution

- **Habitat Degradation:** Elevated water temperatures can alter aquatic habitats, making them unsuitable for native species. Species adapted to cooler temperatures may be displaced, leading to shifts in biodiversity and ecosystem structure.
- **Reduced Oxygen Levels:** Warm water holds less dissolved oxygen than cold water. Increased water temperatures can lead to reduced oxygen levels, particularly in deeper water layers, which can stress or suffocate aquatic organisms.
- **Altered Reproduction and Growth:** Thermal pollution can disrupt the reproductive cycles and growth rates of aquatic organisms. Many species have specific temperature requirements for spawning and development, and deviations from these optimal conditions can affect their reproductive success and survival.
- **Toxicity and Disease:** High water temperatures can exacerbate the toxicity of certain pollutants and promote the growth of harmful bacteria and pathogens. This can increase the incidence of waterborne diseases and mortality rates among aquatic organisms.
- **Impacts on Food Chains:** Changes in water temperature can affect the distribution and abundance of plankton, algae, and other primary producers, which form the base of aquatic food chains. Disruptions to these food chains can have cascading effects on higher trophic levels, including fish, birds, and mammals.

Measures to Control Thermal Pollution

Global Initiatives

- **Water Reuse and Recycling:** Encouraging industries to reuse and recycle water can help reduce the need for fresh water intake and minimize thermal discharges associated with water cooling systems.
  - **Example:** Singapore implements NEWater, a water recycling initiative that treats wastewater to produce high-quality reclaimed water.
    - By reusing treated wastewater for industrial processes and cooling purposes, Singapore reduces freshwater intake and minimizes thermal discharges into surrounding water bodies.
- **Emission Standards:** Governments set emission standards and guidelines to limit the temperature of thermal discharges from industries and power plants, ensuring that aquatic ecosystems are protected from excessive heat.
  - **Example:** The United States Environmental Protection Agency (EPA) sets National Pollutant Discharge Elimination System (NPDES) permits for industrial facilities, including power plants, to regulate thermal discharges.
    - These permits specify temperature limits and require industries to adopt measures to minimize thermal pollution.
- **Research and Innovation:** Ongoing research and development efforts focus on developing new technologies and solutions for mitigating thermal pollution, including innovative cooling technologies, alternative energy sources, and nature-based solutions such as green infrastructure.
  - **Example:** The Clean Energy Research Center (CERC) in China conducts research on advanced cooling technologies for thermal power plants, including dry cooling systems and hybrid cooling solutions.
    - These technologies aim to reduce water consumption and minimize thermal discharges, contributing to environmental sustainability.

India's Initiatives

- **Regulatory Framework:** Helps in enforcing environmental regulations and standards related to thermal pollution.
  - **Example:** The Water (Prevention and Control of Pollution) Act, 1974, and the Environment (Protection) Act, 1986, empower the Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs) to enforce regulations related to thermal pollution.
    - These regulations include limits on the temperature of thermal discharges and requirements for obtaining environmental clearances before commencing operations.
- **Environmental Clearances:** Industries and power plants are required to obtain environmental clearances from regulatory authorities before commencing operations.
  - **Example:** The Ministry of Environment, Forest and Climate Change (MoEFCC) in India issues Environmental Clearance (EC) for industrial projects through its Environmental Impact Assessment (EIA) process.
    - Projects such as thermal power plants are required to submit detailed environmental management plans, including measures to mitigate thermal pollution, before receiving clearance to operate.

- **Technological Upgrades:** Many industries and power plants in India have invested in advanced cooling technologies to minimize thermal discharges such as the adoption of closed-loop cooling systems, cooling towers with improved efficiency, and heat exchangers to recover waste heat.
  - **Example:** Tata Steel's Jamshedpur plant in India implemented a Closed Loop Cooling System (CLCS) to reduce thermal pollution.
    - The CLCS recirculates water within the cooling system, minimizing the need for fresh water intake and reducing thermal discharges into the adjacent Subarnarekha River.
- **Effluent Treatment Plants (ETPs):** Industries are mandated to install effluent treatment plants to treat wastewater before discharge, ensuring that thermal discharges meet permissible limits and do not harm aquatic ecosystems.
  - **Example:** The Narora Atomic Power Station (NAPS) in Uttar Pradesh, India, operates an Effluent Treatment Plant (ETP) to treat wastewater from its cooling systems.
    - The ETP removes heat and contaminants from the discharged water, ensuring compliance with thermal pollution regulations and protecting the Ganges River ecosystem.

Challenges in Measures Taken to Control Thermal Pollution

- **Technological Limitations:** Retrofitting older industrial facilities for advanced cooling technologies is costly and technically challenging, leading to significant downtime.
- **Cost Implications:** Implementing thermal pollution control measures requires substantial capital investment and ongoing operational costs, which are especially burdensome for small and medium-sized enterprises.
  - **Example:** As per World Bank estimates, implementing cooling water treatment technologies in industries can incur an additional operational cost of 10-20% of the total operational budget, posing a significant financial burden for small and medium-sized enterprises (SMEs).
- **Resource Constraints:** Limited availability of water resources, particularly in water-stressed regions, hampers efforts to control thermal pollution due to competition from other sectors like agriculture and urbanization.
  - **Example:** In regions like the Middle East and North Africa (MENA), water-stressed areas face increasing competition for water resources from agriculture, urbanization, and industry.

    {According to the **World Resources Institute (WRI), 14** out of **33** countries in the **MENA region** suffer from **high or extremely high water stress.**}
- **Regulatory Compliance:** Inadequate enforcement and loopholes in regulations undermine the effectiveness of thermal pollution control measures, allowing non-compliant industries to persist.
  - **Example:** A study published in the Journal of Environmental Management found that in many developing countries, including India, regulatory agencies lack the resources and capacity for effective enforcement of thermal pollution regulations, leading to non-compliance by industries.
- **Climate Change Impacts:** Climate change worsens thermal pollution by altering water availability and increasing ambient temperatures, amplifying challenges in controlling thermal discharges.
  - **Example:** A study published in the journal, 'Nature Climate Change' projected that rising temperatures due to climate change could increase the frequency and intensity of heatwaves, exacerbating thermal pollution in water bodies and posing challenges for cooling water management in industries and power plants.

Way Forward

- **Cooling Technologies:** Implementing advanced cooling technologies such as cooling towers, evaporative coolers, and heat exchangers can help industries and power plants reduce the temperature of their discharged effluent before it is released into water bodies.
- **Water Recycling and Reuse:** Promoting the reuse and recycling of cooling water within industrial processes and power plants can reduce the volume of water withdrawn from natural water sources and minimize the discharge of heated effluent into water bodies.
- **Effluent Temperature Regulation:** Establishing environmental regulations and standards to limit the temperature of discharged effluent from industrial facilities and power plants can help protect sensitive aquatic ecosystems from the adverse effects of thermal pollution.
- **Land Use Planning and Vegetation Restoration:** Implementing land use planning strategies to protect and restore riparian habitats, wetlands, and natural vegetation along water bodies can help regulate water temperatures and mitigate the effects of thermal pollution.
- **Alternative Energy Sources:** Promoting the use of alternative energy sources such as renewable energy (e.g., solar, wind, hydroelectric) and energy efficiency measures can reduce the reliance on thermoelectric power generation, which is a significant source of thermal pollution. Transitioning to cleaner and more sustainable energy sources can help mitigate the generation of heat-related pollutants and minimize the impact on aquatic ecosystems.
- **Public Awareness and Education:** Raising public awareness about the impacts of thermal pollution on aquatic ecosystems and the importance of water conservation and sustainable energy practices can foster community engagement and support for pollution control measures. Educational initiatives, outreach programs, and stakeholder consultations can empower individuals, businesses, and policymakers to take action to address thermal pollution and protect water resources for future generations.

Addressing thermal pollution requires a multi-faceted approach that combines technological innovation, improved water management practices, and stringent regulatory measures. Investment in advanced cooling technologies, such as closed-loop cooling systems and heat exchangers, can minimize the thermal impact of industrial processes and power generation.

Additionally, implementing effective monitoring and enforcement mechanisms, along with promoting sustainable urban development practices, can help mitigate the adverse effects of thermal pollution on water bodies. By recognizing the significance of thermal pollution and taking proactive measures to reduce its impact, we can safeguard aquatic ecosystems, protect biodiversity, and ensure the sustainable use of water resources for current and future generations.

CONTEMPORARY NEWS

Zero Liquid Discharge (ZLD)

- **Concept:** ZLD is a wastewater treatment process aiming to eliminate all liquid waste from a facility. This is achieved through a combination of treatment methods like evaporation, crystallization, and membrane separation.
- **Applications:** ZLD is commonly used in industries with high-volume wastewater streams containing pollutants or hazardous materials. Examples include:
  - Chemical industry
  - Pharmaceutical industry
  - Power plants
- **Benefits:**
  - **Reduced environmental impact:** Eliminates the discharge of potentially harmful wastewater into the environment.
  - **Water conservation:** Recovers and recycles water for reuse within the facility, reducing freshwater consumption.
- **Challenges:**
  - **High costs:** Implementing and operating ZLD systems can be expensive due to the complex technology involved.
  - **Energy consumption:** Some ZLD processes require significant energy input, raising concerns about sustainability.

The Right to Repair Movement

- **Concept:** This movement advocates for consumers' right to repair their own electronic devices or access independent repair services.
- **Concerns:** Manufacturers often restrict access to repair manuals, tools, and spare parts, making it difficult or expensive for consumers to repair their devices themselves. This can lead to:
  - **Increased electronic waste:** Devices are discarded prematurely due to repairability issues.
  - **Reduced consumer choice:** Limited repair options can force consumers to purchase new devices instead of repairing existing ones.
- **Goals of the movement:**
  - **Promote repairability:** Encourage manufacturers to design devices with ease of repair in mind.
  - **Ensure access to repair resources:** Advocate for consumers' right to access repair manuals, parts, and tools.
  - **Combat e-waste:** Extend the lifespan of electronic devices and reduce unnecessary waste.

Bubble curtain

- **Concept:** A bubble curtain is a vertical barrier of air bubbles created underwater using an air compressor and diffuser.
- **Applications:** Bubble curtains have various applications, including:
  - **Pollution control:** Can be used to contain oil spills, prevent sediment dispersion, and control the spread of pollutants in water bodies.
  - **Marine noise reduction:** Mitigate underwater noise pollution from sources like construction activities or sonar, protecting marine life.
  - **Habitat protection:** Create artificial barriers to guide fish towards specific areas or deter them from entering sensitive zones.
- **Working principle:** The rising air bubbles create a physical barrier that disrupts water flow and can trap or divert pollutants, sound waves, or marine life depending on the application.
- **Limitations:**
  - Effectiveness can be limited by factors like water current, bubble size, and depth.
  - May not be suitable for all environments due to potential ecological impacts or cost considerations.

Per and Polyfluoroalkyl Substances (PFAS)

- Per- and polyfluoroalkyl substances (PFAS) are a group of synthetic chemicals used in various industrial and consumer products, including firefighting foams, non-stick cookware, stain-resistant fabrics, and food packaging.
- PFAS are persistent in the environment and can accumulate in soil, water, air, and biota.
- They are of concern due to their potential adverse effects on human health and the environment, including links to cancer, immune system dysfunction, developmental effects, and environmental persistence.
- Efforts to address PFAS contamination include research, regulation, and remediation measures to reduce exposure and mitigate environmental impacts.

❑ Nanoplastics

- Researchers have developed a new, metallic fingerprint-based method to detect and measure the amount of nanoplastics in organisms.
- Researchers exposed lettuce plants to nanoplastics from commonly found plastic waste in environment — polystyrene (PS) and polyvinyl chloride (PVC) nanoplastics.
- **Nanoplastics:** Smaller than 1,000 nanometre (1 nm is equal to one billionth of a metre).
- Can lead to cell damage and inflammation in humans; growth impairments, larval deformities and other toxic effects in marine organisms.

❑ Bharat Tap initiative

- The Ministry of Housing and Urban Affairs (MoHUA) has launched the Bharat Tap initiative.
- Conducted under the aegis of Atal Mission for Rejuvenation and Transformation 2.0 (AMRUT) and Swachh Bharat Mission 2.0 (SBM).
- Aim: To provide low-flow, sanitary-ware at scale, and thereby reduce water consumption at source considerably.
- Estimated to save a minimum of 40% water, which in turn results into energy savings.

❑ 'Nirmal Jal Prayas'

- MoHUA launched 'Nirmal Jal Prayas', initiative of the National Real Estate Development Council (NAREDCO) Mahi.
- **Aim:** To map ground water and save 500 crore litres of water per annum.
- Through the initiative, advocacy, awareness and amplification towards saving water will be disseminated and highlighted.
- **NAREDCO:** An autonomous self-regulatory body, established in 1998, under aegis of MoHUA.
- It strives to be the collective force influencing and shaping real estate industry.
- NAREDCO had established Mahi - NAREDCO Women's Wing for empowering women entrepreneurs and encouraging participation of women in real estate sector and allied fields.

❑ India's first Swachh Sujal Pradesh

- Andaman and Nicobar (A&N) Islands have become India's first Swachh Sujal Pradesh.
- Swachh Sujal Pradesh certification: Provided by Ministry of Jal Shakti, 3 important components:
- Safe and secure drinking water supply and management.
- **ODF (open defecation free) Plus:** ODF Sustainability and Solid and Liquid Waste Management (SLWM), and Cross-cutting interventions like convergence, IEC (Information, Education Communication), action planning, etc.
- All villages on A&N Islands have received Har Ghar Jal certification.

Other Water Pollutants in News

❑ Chlorpyrifos, fipronil, atrazine and paraquat

- According to a report by the Pesticide Action Network (PAN) a non-profit body, chlorpyrifos, fipronil, atrazine and paraquat are being used in excess in various states than what has been recommended by the Central Insecticides Board and Registration Committee, India's pesticides regulator.
  - ❒ Chlorpyrifos is used to control foliage and soil-borne insect pests.
  - ❒ Fipronil is used to control ants, beetles, cockroaches, fleas, etc.
  - ❒ Atrazine is used to selectively control annual grasses and broadleaf weeds before they emerge.
  - ❒ Paraquat is a herbicide used primarily to controlling weeds and grasses.

❑ Nonylphenol (NP)

- A study revealed the presence of high levels of toxic chemical NP in drinking water across India.
- Nonylphenol is commonly used in the production of Nonylphenol Ethoxylates (NPEs).
- NPEs used as surfactants and in day-to-day consumer products such as detergents, wetting agents and dispersants.
- **Impacts in Humans:** Endocrine disruptor associated with adverse effects like birth defects, skin and eye irritation etc.
- United Nations Environment Programme (UNEP) has designated NP as a chemical of global concern.
- No standards exclusively for NP in drinking and surface waters in India.

CONCLUSION

Pollution poses a critical threat to human health, biodiversity, and the environment at large. Its pervasive presence in various forms, including air, water, soil, and noise pollution, necessitates urgent action to mitigate its detrimental effects. Pollution levels are increasing in quantity and severity due to increasing population with increasing consumption and linear production system (rather than circular) rooted in anthropogenic view of nature and its resources.

Through concerted efforts such as regulations, technological innovations, and sustainable practices, we can work towards a cleaner and healthier planet for current and future generations. Addressing pollution requires collective responsibility and commitment to safeguarding the delicate balance of our ecosystems and ensuring the well-being of all life forms on Earth.

Waste Management

10

INTRODUCTION

Waste has always existed in our homes, neighborhoods, villages, towns, cities, and communities. Waste gives insight into lifestyle, economy, organisation and other aspects of a community. Archeologist reconstruct many aspects of pre historic communities using waste left behind them. Historically, **waste disposal** unfolded haphazardly, reflecting the simplicity of ancient societies. However, in our contemporary landscape, **waste generation** has surged to alarming levels. The exponential increase in population, shifts in lifestyles, and the unbridled expansion of industries, transport, and technology have transformed **waste management** into a critical concern. Today, it not only affects human health and social dynamics but also poses a severe threat to the **environment.** In light of these challenges, this chapter delves into the multifaceted dimensions of **waste management.** From ancient practices to the complexities of the modern era, it scrutinizes the evolution of **waste management,** highlighting the urgency of addressing this intricate issue in our quest for sustainable coexistence.

Waste & Waste Management

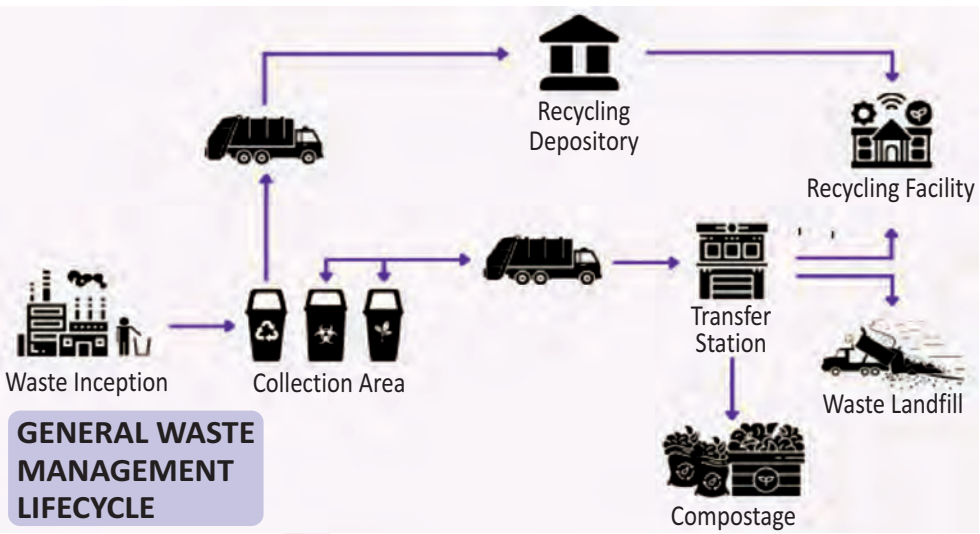


Fig. 10.1: General Waste Management Lifecycle

Wastes, as defined under **the Basel Convention (1990),** encompass substances or objects that are either disposed of, intended for disposal, or mandated for disposal by national laws.

Waste refers to any material, substance, or byproduct that is discarded, unwanted, or no longer useful. It can be generated from various sources, including households, industries, commercial establishments, institutions, and construction activities.

Waste management encompasses the collection, transportation, treatment, recycling, and disposal of waste materials to minimize environmental impacts, public health risks, and resource depletion. Effective waste management strategies aim to reduce waste generation, promote recycling and reuse, and ensure proper treatment and disposal of waste to protect human health and the environment.

Waste management practices vary depending on the type of waste, local regulations, available infrastructure, and sustainability goals, and they often involve a combination of technological, regulatory, and behavioral interventions. Proper waste management is essential for mitigating pollution, conserving resources, and promoting sustainable development. **Waste Management System:** The waste management system refers to an organization's approach to handling waste, encompassing strategies for disposal, reduction, reuse, and prevention of waste. Various waste management methods are employed to address waste-related challenges.

Waste management methods include **recycling, composting, incineration, landfills, bioremediation, waste to energy,** and **waste minimization.**

IGNITE YOUR MIND

Trash Mountain: Imagine a world where towering mountains of waste dominate the landscape, threatening ecosystems and human health. What are the different types of waste we generate, and what are the environmental and health consequences of improper waste management?

CLASSIFICATION OF WASTE

Types of Waste

Waste can be classified into various types based on its origin, composition, and characteristics, including:

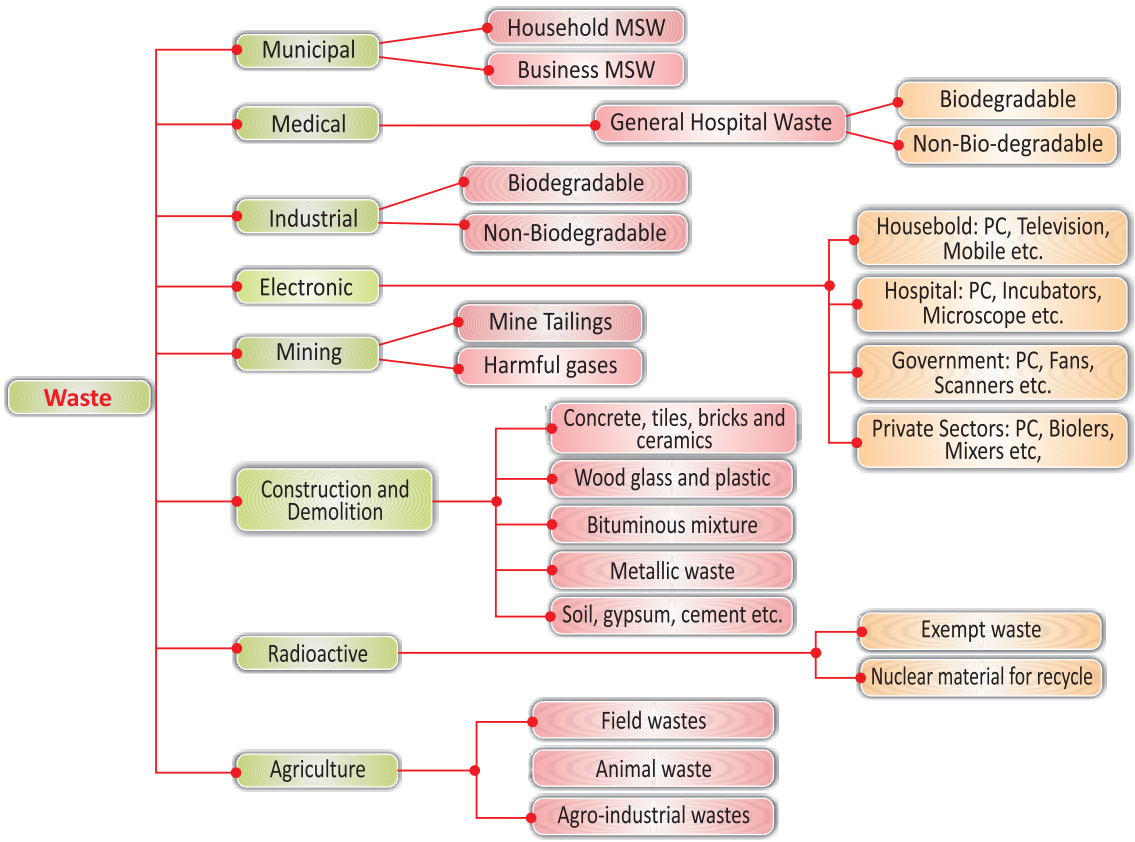


Fig. 10.2: Classification of Waste

Based on Origin

- **Residential Waste:** Generated from households and residential areas, including household trash, food waste, packaging materials, and yard trimmings.
- **Commercial Waste:** Generated from commercial establishments such as offices, shops, restaurants, and markets, including packaging materials, paper waste, and food scraps.
- **Institutional Waste:** Generated from schools, hospitals, government buildings, and other institutions, including paper waste, food waste, and biomedical waste.
- **Industrial Waste:** Generated from manufacturing processes, industrial activities, and construction sites, including process waste, packaging materials, and construction debris.
- **Agricultural and Livestock Waste:** Generated from agriculture and related activities operations, it includes crop residues, dead animals etc.

Based on Composition

- **Organic Waste:** Biodegradable waste derived from plant or animal sources, including food scraps, yard waste, agricultural residues, and organic byproducts.
- **Inorganic Waste:** Non-biodegradable waste that does not decompose easily, including plastics, metals, glass, ceramics, and synthetic materials.
- **Combustible Waste:** Waste that can be burned or incinerated for energy recovery, including paper, cardboard, wood, and some plastics.

- **Non-Combustible Waste:** Waste that cannot be burned or incinerated, including metals, glass, ceramics, and certain plastics.

General Categorization of Waste

- **Non-Hazardous Waste:** Waste that does not pose a significant risk to human health or the environment, including most municipal solid waste and non-toxic industrial waste.
  - **Biomedical Waste:** Waste generated from healthcare facilities, laboratories, and medical practices, including infectious waste, pathological waste, sharps, and pharmaceutical waste.
- **Hazardous Waste:** Waste that exhibits hazardous properties such as toxicity, flammability, reactivity, or corrosivity, requiring special handling, treatment, and disposal.
- **Types of Hazardous waste** can be explained in the following manner:
  - **Toxic Waste:** Waste containing toxic substances that can cause harm to humans, animals, or ecosystems through exposure or contamination.
  - **Flammable Waste:** Waste that can catch fire easily and pose a risk of combustion or explosion, such as solvents, fuels, and certain chemicals.
  - **Corrosive Waste:** Waste that can corrode or damage materials upon contact, including strong acids, alkalis, and corrosive cleaning agents.
  - **Reactive Waste:** Waste that is unstable, reactive, or prone to violent reactions under certain conditions, such as explosives, oxidizers, and reactive metals.
- **Biodegradable Waste:** Organic waste that can be broken down by microorganisms through natural processes of decomposition, including food waste, yard waste, and agricultural residues.
- **Non-Biodegradable Waste:** Waste that does not readily decompose or degrade in the environment, such as plastics, metals, glass, and certain synthetic materials.

Impacts of Waste Accumulation

Environmental Consequences

- **Land Pollution:** Piles of unmanaged waste degrade landscapes, contaminate soil, and disrupt ecosystems.
- **Water Pollution:** Leachate from landfills and runoff from waste sites can contaminate water bodies, harming aquatic life and affecting water quality.
- **Air Pollution:** Open burning of waste releases harmful pollutants into the air, contributing to smog, respiratory illnesses, and climate change. Further, bad odour from waste decreases quality of life in the surrounding.
- **Habitat Destruction:** Improper waste disposal destroys natural habitats, disrupts wildlife habitats, and reduces biodiversity.

Health Implications

- **Disease Spread:** Accumulated waste provides breeding grounds for disease-carrying vectors such as mosquitoes, rats, and flies, increasing the risk of vector-borne diseases.
- **Contamination:** Exposure to toxic chemicals, pathogens, and pollutants from waste can lead to skin diseases, respiratory ailments, gastrointestinal infections, and other health problems.
- **Food Safety:** Improper disposal of waste can contaminate food sources, leading to foodborne illnesses and poisoning among communities living near waste sites.

Economic Effects

- **Cleanup Costs:** Governments and communities incur significant expenses for waste cleanup, remediation of contaminated sites, and restoration of damaged ecosystems.
- **Healthcare Costs:** Treating waste-related illnesses and health conditions places a burden on healthcare systems, leading to increased healthcare expenditures.
- **Lost Productivity:** Illnesses and absenteeism resulting from waste-related health issues reduce workforce productivity and economic output.
- **Tourism and Livelihoods:** Pollution from waste accumulation can deter tourists, affect local economies dependent on tourism, and disrupt livelihoods in affected areas.
- **Quality of Life and Investments:** High unmanaged waste reduces quality of life which reduces investments especially in service sectors and reduces flow of skilled migrants, leading to the region lagging behind in investments and jobs which sets in vicious cycle.

SOLID WASTE

Solid waste refers to any discarded or abandoned material that is not liquid or gaseous in nature. It encompasses a wide range of materials generated from various sources, including households, businesses, industries, institutions, and construction activities. Solid waste can be categorized based on its source, composition and characteristics.

Effective solid waste management involves the collection, transportation, treatment, and disposal of waste in an environmentally sustainable and socially responsible manner. It requires the implementation of waste reduction, recycling, composting, and energy recovery practices to minimize environmental pollution, conserve resources, and protect public health.

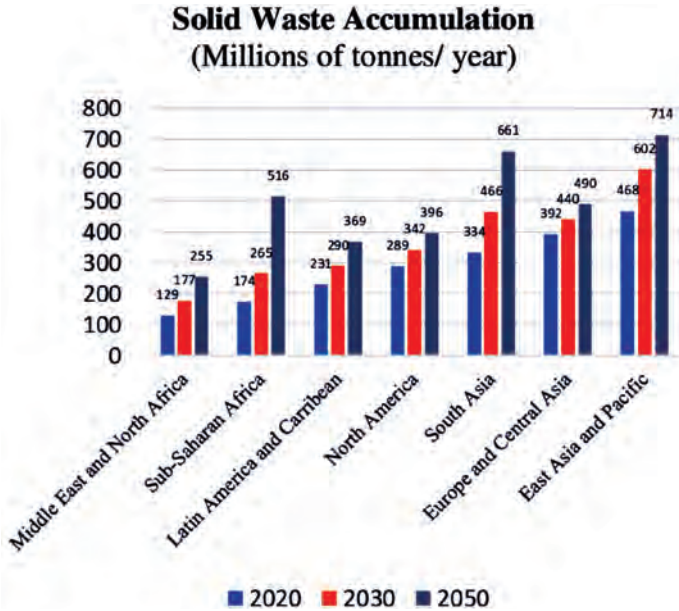


Fig. 10.3: Projection of Solid Waste Accumulation across the World

Types of Solid Waste

Solid waste can be broadly categorized into various types based on its source, composition, and characteristics.

Based on the Source

- **Residential Waste:** Generated from households and residential areas. Includes household garbage, food waste, packaging materials, and yard waste.

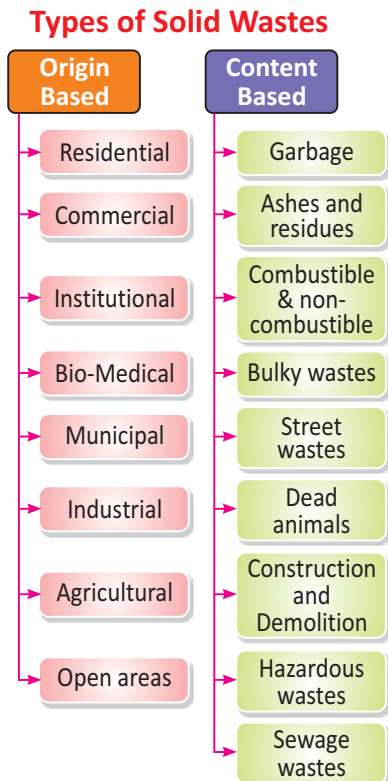


Fig. 10.4: Types of Solid Wastes

- **Commercial Waste:** Generated from commercial establishments, offices, markets, and retail stores. Includes packaging materials, office paper, cardboard, and food waste.
- **Industrial Waste:** Generated from industrial processes and manufacturing activities. Includes manufacturing waste, process waste, and by-products from factories and industrial plants.
- **Institutional Waste:** Generated from institutions such as schools, hospitals, government offices, and prisons. Includes office waste, medical waste, laboratory waste, and educational materials.
- **Construction and Demolition (C&D) Waste:** Generated from construction, renovation, and demolition activities. Includes concrete, bricks, wood, metal, asphalt, and other construction debris.
- **Municipal Solid Waste (MSW):** Waste collected from households, commercial establishments, and public areas by municipal authorities. MSW includes a mix of residential, commercial, and institutional waste, along with street sweepings and bulky waste items.
- **Agriculture waste:** It includes crop residue and dead remains of livestock.

Based on Composition

- **Organic Waste:** Biodegradable waste derived from plant or animal sources. Includes food waste, yard waste, agricultural residues, and sewage sludge.
- **Inorganic Waste:** Non-biodegradable waste composed of materials such as metals, glass, plastics, and ceramics. Includes packaging materials, household items, and industrial by-products.
- **Hazardous Waste:** Waste that poses a risk to human health or the environment due to its toxic, flammable, corrosive, or reactive properties. Includes chemicals, solvents, pesticides, batteries, and electronic waste.
- **Recyclable Waste:** Materials that can be recycled or reused to produce new products. Includes paper, cardboard, plastics, glass, metals, and electronic waste.
- **Non-Recyclable Waste:** Materials that cannot be recycled due to contamination, degradation, or lack of recycling infrastructure. Includes certain plastics, contaminated paper, and mixed waste.

Based on Characteristics

- **Biomedical Waste:** Waste generated from healthcare facilities, research laboratories, and medical clinics. Includes sharps, infectious waste, pathological waste, pharmaceuticals, and radioactive materials.
- **Electronic Waste (E-Waste):** Waste generated from discarded electronic devices and appliances. Includes computers, laptops, smartphones, televisions, refrigerators, and other electronic gadgets.

- **Construction and Demolition (C&D) Waste:** Waste generated from construction, renovation, and demolition activities. Includes concrete, bricks, wood, metal, asphalt, and other construction debris.
- **Toxic Waste:** Waste containing hazardous substances that can cause harm to human health or the environment. Includes chemicals, heavy metals, pesticides, and industrial by-products.

Status of Solid Waste Generation

Solid Waste Generation Statistics

Aspects	India	World
Total waste generation (year)	62 million tonnes (2021-22)	2.01 billion tonnes (2018)
Per capita waste generation (kg per day)	Urban: 0.46 Rural: 0.31	Global average: 0.74
Sources of waste	Household: 50-60% Commercial: 15-20% Construction and demolition: 10-15% Industrial: 5-10% Agricultural: 5-10%	N/A
Waste collection rate	Urban: Around 80% Rural: Significantly lower	High-income countries: 86% Low-income countries: 31%
Waste treatment	Composting: 12% Landfill: 18% Unprocessed/open dumping: 70%	Landfill: 50% Incineration: 12% Composting & anaerobic digestion: 4% Recycling and reuse: 9% Open dumping: 15%

Global

- Around the world, waste generation rates are rising. In 2020, the world was estimated to generate 2.24 billion tonnes of solid waste, amounting to a footprint of 0.79 kilograms per person per day. (World Bank)
- With rapid population growth and urbanization, annual waste generation is expected to increase by 73% from 2020 levels to 3.88 billion tonnes in 2050.

India

- According to the **2023 State of India's Environment report,** India generates around **150,000 tonnes of municipal solid waste (MSW) every day.**
- **The collection efficiency** of the waste generated is **95.4%.**
- **50% of the solid waste is treated while 14% is landfilled.**

Municipal Solid Waste

- Municipal Solid Waste (MSW)—more commonly known as **trash or garbage**—consists of everyday items we use and then throw away, such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. This comes from our homes, schools, hospitals, and businesses.
- MSW typically includes a wide range of materials such as paper, cardboard, food scraps, plastics, glass, metals, textiles, yard waste, and household hazardous waste like batteries and chemicals.

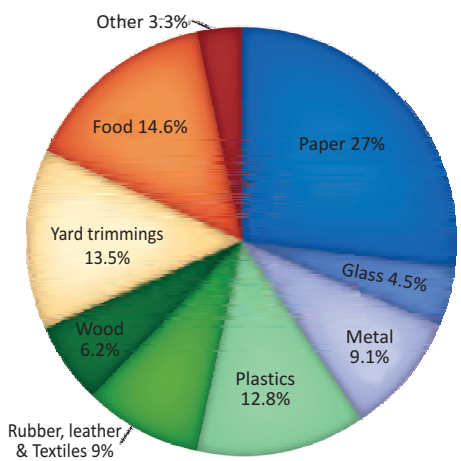


Fig. 10.5: Percentage of items under Municipal Solid Waste

Types of Municipal Solid Waste

- **Organic Waste:** This includes **food scraps, yard waste,** and **other biodegradable materials.**
- **Paper and Cardboard:** Newspapers, magazines, cardboard boxes, and other paper-based materials.
- **Plastics:** Various types of plastic containers, bags, packaging materials, and other plastic products.
- **Glass:** Bottles, jars, and other glass containers.
- **Metals:** Aluminum cans, steel cans, tin cans, and other metal products.
- **Textiles:** Clothing, linens, curtains, and other fabric-based materials.
- **Electronic Waste (E-Waste):** Discarded electronic devices such as computers, TVs, smartphones, and appliances.
- **Hazardous Waste:** Batteries, paints, solvents, pesticides, and other potentially harmful materials.

Sources of Municipal Solid Waste

- Municipal Solid is generated by Residential, Commercial, Institutional, Municipal services/Street Litter, Construction and Demolition and other sources.

Status of Municipal Solid Waste Generation India

- The total waste generated in India was **152,245 Metric Tons Per Day(MT/D).**
- Out of this **114,183 MT/D (75%)** of waste is processed.
- **Central Pollution Control Board (CPCB)** recently projected that annual waste generation in India will increase to 165 MT by 2030.

International Day of Zero Waste 2023 - March 30

- On December 14,2022, The United Nations General Assembly formally recognized the importance of zero-waste initiatives and proclaimed **March 30 as the International Day of Zero Waste, to be observed annually beginning in 2023.**
- The International Day of Zero Waste aims to promote **sustainable consumption and production patterns** and raise awareness about how zero-waste initiatives contribute to the advancement of the 2030 Agenda for Sustainable Development.
- Zero waste initiatives seek to maximize recycling, minimize waste, reduce consumption and ensure that products are made to be reused, repaired or recycled back into nature or the marketplace.
- According to the general standard, any town which achieves processing of upto 80 percent of waste can be claimed to be a **'zero waste town'**.
- **Examples:**
  - **Titabor**, a small town in **Jorhat district** of **Assam** became the first **'zero waste town'** in Assam by processing nearly 80% of the waste generated.
  - **Navjivan Vihar** is the **first zero-waste locality** in **New Delhi.**

Legacy Waste Definition

Legacy waste, also known as old municipal solid waste (OMSW), refers to accumulated, unmanaged waste dumpsites in India, posing significant environmental and health risks. These mountains of garbage, often decades old, contain a mix of organic matter, plastics, metals, glass, and other materials, often exceeding tens of millions of tonnes.

Issues with Legacy Landfills

- Lack of data on landfill sites and improper waste segmentation and management.
- Legacy waste often contains mountains of improperly managed waste.

Utilization of Legacy Waste

- Scientific mining of legacy waste can create a viable business model.
- RDF from polymeric wastes for energy recovery, and recovery of building materials from fine fractions.

Steps Taken

- The Ministry of Housing and Urban Affairs is actively rehabilitating legacy landfills under Swachh Bharat Mission (Urban) 2.0.
- Public dashboard monitoring the status of 2,200 legacy landfill sites to be available soon.
- **Swachh Bharat Mission-Urban 2.0:**
  - Aims to make all cities 'Garbage Free' and manage grey and black water effectively.
  - Focuses on source segregation, scientific processing of municipal solid waste, and remediating legacy dumpsites.
  - Action plans consider garbage components, including construction and demolition (C&D) waste, **refuse derived fuel (RDF) for industries**, and bio-soil for different purposes.

Municipal Solid Waste Management

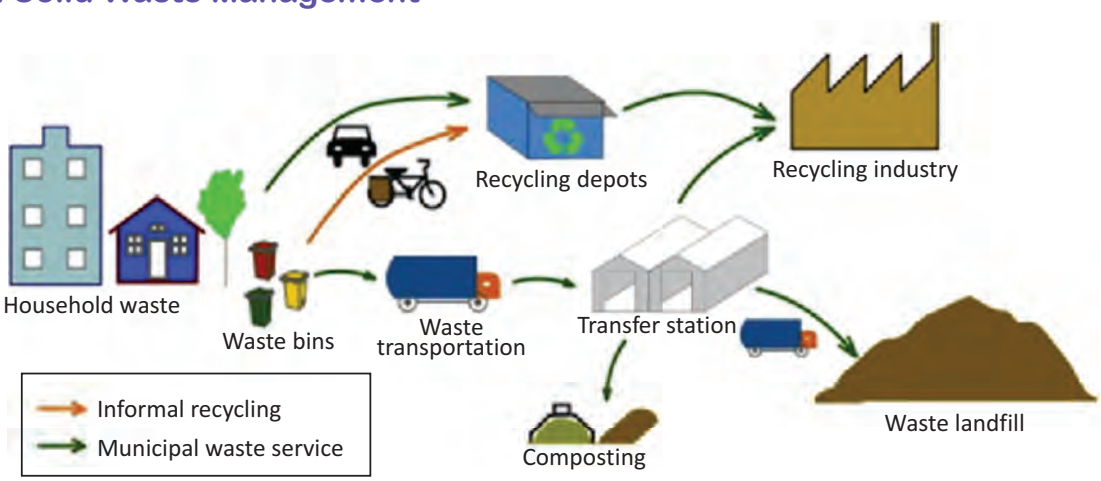


Fig. 10.6: Municipal Solid Waste Management (at a glance)

Measures to Control MSW

Global Initiatives

- **European Union Circular Economy Action Plan:** Aims to transform the EU into a circular economy by minimizing waste and maximizing resource reuse. This includes promoting eco-design, producer responsibility, and waste prevention strategies.
- **Food waste reduction initiatives:** Many countries, like France and Italy, have implemented bans on food waste disposal in landfills and encouraged food donation programs.
- **Deposit-refund schemes:** Several countries, like Germany and Sweden, have successful deposit-refund schemes for beverage containers, encouraging recycling and reducing litter.

National Initiatives

- **Swachh Bharat Mission (SBM-Urban):** Launched in 2014, this flagship program aims for 100% waste collection and scientific processing by 2026. It focuses on building infrastructure, waste segregation, and public awareness.
- **Waste to Wealth Mission:** Launched in 2017, this initiative promotes processing waste into valuable resources like compost, fuel, and recycled materials. It supports setting up decentralized processing units and creating markets for recycled products.
- **Composting initiatives:** The government encourages composting of organic waste through programs like **GOBAR-dhan (Galvanizing Organic Bio-Agro Resources Dhan)** and decentralized composting units.
  - The **Union Budget 2023-24** envisioned the establishment of **500 Waste to Wealth plants** under the **GOBARdhan (Galvanizing Organic Bio-Agro Resources Dhan) scheme** with a total investment of **Rs 10,000 crore.**
- **Policy measures:** Regulations like the **Plastic Waste Management Rules, 2016**, **Solid Waste Management Rules, 2016** and **E-Waste Management Rules, 2022** aim to reduce overall waste generation and improve recycling.

Challenges in Municipal Solid Waste Management

1. **Lack of Segregation at Source:** Most waste gets mixed at the household level, making composting and recycling difficult and expensive.
   - **Only 43%** of waste is segregated at source, leading to **57% mixed waste,** making processing inefficient. **(Central Pollution Control Board (CPCB) Annual Report 2020-21)**
2. **Inadequate Infrastructure:** Many cities lack collection systems, processing facilities, and landfills, leading to open dumping and burning.
   - According to the **World Bank Report "What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050",** India lacks sufficient landfills, with only 300 sanitary landfills serving 70% of the urban population.
3. **Informal Sector Dependence:** Informal waste pickers collect a significant portion of waste, but their working conditions are often poor and lack access to proper sorting and recycling facilities.
   - As per the **International Labour Organization (ILO), 15-20 million informal** waste pickers collect **70%** of recyclable waste, but face health risks and lack formal recognition.
4. **Public Awareness and Behavior Change:** Low public awareness and lack of behavior change regarding waste minimization, segregation, and composting hinder effective waste management.
   - A 2020 survey revealed **only 35%** of urban households practiced waste segregation, indicating a need for awareness campaigns.
5. **Policy and Enforcement:** Comptroller and Auditor General (CAG) of India report on **"Performance Audit of Solid Waste Management"** highlights **weak enforcement** of waste management regulations, hindering effectiveness.
6. **Low impetus to recycling industry:** Low development of functional linkages in the recycling industry hinders effective management of municipal solid waste along with potential economic losses.
   - As per the estimates by the **Ministry of Environment, Forests and Climate Change,** India produces **62 million tonnes of waste** annually, which is increasing at an average **annual rate of 4%.**
   - Despite being home to a potentially **15 billion dollar** waste industry, **only 20%** of this waste is **recycled**.

Roadmap for Effective Municipal Solid Waste Management

1. **Waste Segregation at Source:**
   - **Mandatory waste segregation:** Implement stricter regulations and enforce penalties for non-compliance.
   - **Public awareness campaigns:** Educate residents about segregation methods and benefits through multimedia channels and community engagement.
   - **Provide infrastructure:** Distribute color-coded bins and collection systems for segregated waste to each household.
2. **Strengthen Infrastructure and Technology:**
   - **Invest in decentralized processing units:** Set up composting facilities, bio-gas plants, and recycling centres near waste generation points.
   - **Modernize landfills:** Develop sanitary landfills with leachate and gas collection systems, prioritizing waste-to-energy plants where feasible.

- **Promote innovation:** Support research and development of advanced waste processing technologies like plasma gasification and anaerobic digestion.

3. **Empowering the Informal Sector:**
   - **Formalize waste pickers:** Integrate them into the formal waste management system through training, IDs, and social security benefits.
   - **Provide access to technology:** Equip waste pickers with sorting equipment and protective gear to improve efficiency and safety.
   - **Facilitate collaboration:** Encourage partnerships between municipalities and waste picker cooperatives for better waste collection and processing.
4. **Behavior Change and Education:**
   - **Launch sustained awareness campaigns:** Utilize mass media, schools, and community events to educate people on waste reduction, composting, and responsible disposal.
   - **Incentivize responsible behavior:** Implement reward systems for waste segregation and composting, and introduce penalties for littering and improper waste disposal.
   - **Promote producer responsibility:** Advocate for EPR policies that hold manufacturers accountable for the end-of-life management of their products.
5. **Financing and Sustainability:**
   - **Explore innovative funding mechanisms:** Utilize public-private partnerships, waste-to-wealth projects, and carbon credits to attract investments.
   - **Strengthen financial management:** Improve budgeting and resource allocation within municipalities for efficient waste management.
   - **Promote user fees:** Implement fair and transparent user fees to offset operational costs and incentivize waste reduction.
6. **Policy and Enforcement:**
   - **Strengthen existing regulations:** Refine and strictly enforce existing waste management rules, including penalties for non-compliance.
   - **Develop comprehensive EPR policies:** Establish regulations that hold manufacturers responsible for product life cycle management and waste reduction.
   - **Promote transparency and accountability:** Implement transparent monitoring systems and hold authorities accountable for achieving waste management goals.
7. **Data-driven Decision Making:**
   - **Invest in data collection and analysis:** Build robust data management systems to track waste generation, composition, and processing efficiency.
   - **Utilize data for informed decision-making:** Use data to identify hotspots, optimize waste collection routes, and evaluate the effectiveness of interventions.
   - **Promote knowledge sharing:** Share best practices and lessons learned across different cities and states to accelerate progress.

This roadmap is a starting point, and continuous adaptation and innovation will be necessary to address the evolving challenges of waste management in India. The success of this approach hinges on **strong political will, public participation, and collaboration between various stakeholders.**

By implementing these strategies collaboratively and addressing the specific challenges of different regions, India can move towards a more **sustainable** and **effective** municipal solid waste management system.

Causes of Solid Waste Accumulation

- **Unsustainable Consumption**: Excessive purchasing and usage contribute to heightened waste production, exacerbated by non-biodegradable packaging and products designed for short lifespans. Companies are creating products with short life cycles to maintain high demand for their products. Further, maintenance and repair are not always encouraged and when done are at such a high cost and with such conditions that it is economically prohibitive.
- **Inadequate Waste Management:** Insufficient infrastructure for waste collection, recycling, and composting leads to unmanaged waste, with improper disposal methods like open dumping and burning, polluting the environment.
- **Industrial Impact:** Manufacturing processes and construction activities generate substantial waste, including hazardous materials, while unsustainable farming practices contribute agricultural waste.
- **Lack of Awareness and Education:** Limited understanding of consequences of waste coupled with inadequate education on waste management, hampers individual and community efforts to address the issue, exacerbated by neglect of producer responsibility.
- **Population Growth and Urbanization:** Increasing populations and rapid urbanization strain waste management systems, concentrating waste generation in urban areas and exacerbating existing challenges.

Consequences of Solid Waste Accumulation

- **Pollution and Degradation:** Improper waste management pollutes air, water, and soil, harming ecosystems and biodiversity. Landfills emit greenhouse gases and harmful chemicals.
- **Public Health Risks:** Waste attracts disease-carrying pests, and burning it releases toxic air pollutants, leading to respiratory problems and other health risks. Improper hazardous waste disposal can have long-term health effects.

- **Economic Costs:** Inefficient waste management leads to high collection, transportation, and disposal costs, along with healthcare expenses related to waste-related illnesses and environmental cleanup. Tourism and property values can also decline in affected areas.
- **Social Inequalities:** Poor waste management disproportionately impacts marginalized communities, with informal waste pickers facing health risks and poor living conditions. It also diminishes the quality of life and can lead to social unrest.
- **Resource Depletion:** Landfills occupy land and waste valuable resources that could be recovered and reused. Inefficient waste management perpetuates a resource-intensive consumption model.

SOLID WASTE MANAGEMENT

"Solid waste management" encompasses the complete process of collecting, treating, and disposing of solid waste. Waste is sourced from diverse origins and undergoes disposal within the waste management framework. The process involves collecting, transporting, treating, analyzing, and disposing of waste.

Solid Waste Management Cycle

The solid waste management cycle encompasses the various stages involved in the handling, treatment, and disposal of solid waste to minimize environmental impacts and promote sustainability.

Key Stages in the Solid Waste Management Cycle

- **Generation:** The cycle begins with the generation of solid waste, which includes various types of waste produced by households, businesses, industries, and institutions. Solid waste can be classified into different categories such as organic (biodegradable), recyclable, hazardous, and inert waste.
- **Collection:** After waste is generated, it needs to be collected from its source. Collection methods vary depending on the type of waste, location, and infrastructure. Common collection methods include curbside collection, door-to-door collection, drop-off points, and community bins.

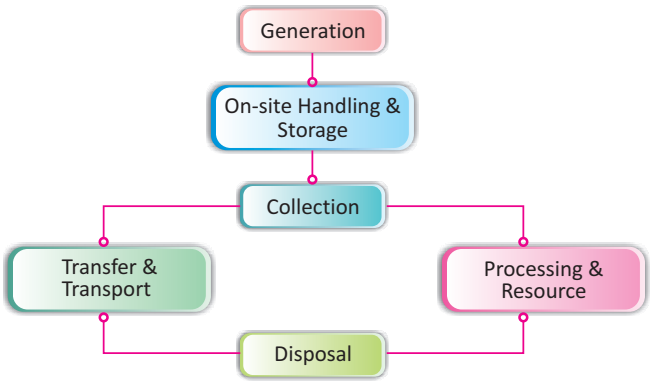


Fig. 10.7: Solid Waste Management Cycle

- **Transportation:** Once collected, solid waste is transported to treatment and disposal facilities. Transportation methods may involve trucks, compactors, or other specialized vehicles depending on the volume and type of waste.
- **Treatment and Processing:** Solid waste undergoes various treatment and processing methods to reduce its volume, minimize environmental impacts, and recover valuable resources. Treatment methods include composting for organic waste, recycling for recyclable materials, and energy recovery through waste-to-energy processes. Hazardous waste requires specialized treatment to neutralize or contain its harmful effects.
- **Disposal:** The final stage of the solid waste management cycle involves the disposal of waste that cannot be recycled, composted, or recovered. Common disposal methods include landfilling, incineration, and sanitary landfilling. Proper disposal practices aim to minimize environmental pollution, groundwater contamination, and public health risks.

Methods of Disposal of Solid Waste

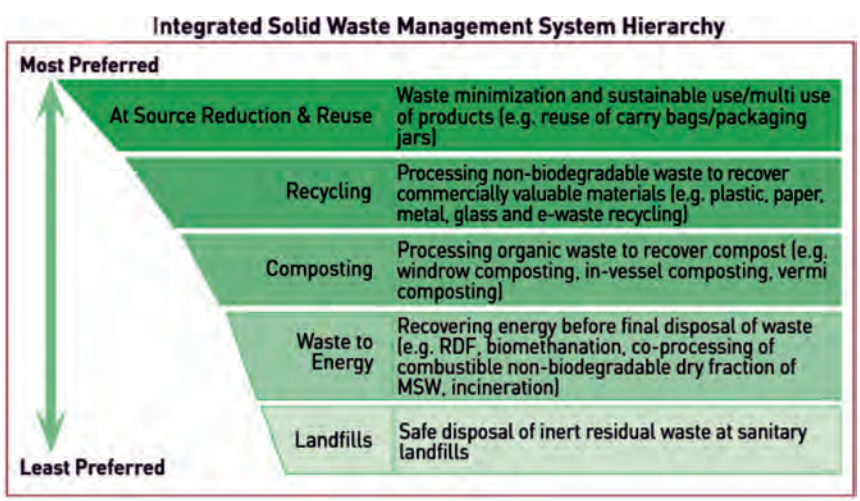

Integrated Solid Waste Management System Hierarchy
Most Preferred
At Source Reduction & Reuse
Waste minimization and sustainable use/multi use of products (e.g. reuse of carry bags/packaging jars)
Recycling
Processing non-biodegradable waste to recover commercially valuable materials (e.g. plastic, paper, metal, glass and e-waste recycling)
Composting
Processing organic waste to recover compost (e.g. windrow composting, in-vessel composting, vermi composting)
Waste to Energy
Recovering energy before final disposal of waste (e.g. RDF, biomethanation, co-processing of combustible non-biodegradable dry fraction of MSW, incineration)
Landfills
Safe disposal of inert residual waste at sanitary landfills
Least Preferred

Fig. 10.8

1. Landfills

- Landfills are the most common method of solid waste disposal, involving the burial of waste in designated areas.
- Waste is compacted and deposited in engineered pits or trenches, with layers of soil or other materials used to cover and isolate the waste.
- Landfills require proper design, construction, and management to prevent environmental contamination and mitigate health risks.
- Modern landfills incorporate liners, leachate collection systems, and gas management systems to control pollution and minimize environmental impacts.
- **Example:** Bhalswa landfill, Ghazipur landfill in India.

Landfill Concept

- **Definition:** Landfills are man made pits used for the disposal of solid waste by stacking, compacting, and covering it with earth or other materials.
- **Composition:** Landfills contain various types of waste, including household, commercial, and industrial waste, along with plastic, metal, and organic materials.
- **Protective Measures:** Landfills are lined to prevent the leakage of hazardous chemicals into groundwater and covered to deter pests and reduce odor.
- **Location:** Typically situated in areas with low flood risk and groundwater levels to minimize environmental contamination.

Landfill Gas

- **Generation:** Landfills produce methane and other gases through anaerobic digestion of waste by bacteria.
- **Utilization:** Collected landfill gas can be used for energy generation and various industrial applications.
- **Monitoring:** Regular monitoring of landfill gas levels is essential to prevent accidents and ensure worker safety.

Sanitary Landfill Disposal

- **Definition:** Modern sanitary landfills are designed to minimize environmental impact and protect groundwater quality.
- **Waste Segregation:** Lighter materials are placed at the bottom, while hazardous substances are buried deeper to prevent contamination.
- **Covering:** Each day's new waste is covered with soil to facilitate decomposition and prevent groundwater contamination.
- **Challenges:** Requires ongoing maintenance, wastewater treatment, and gas recovery to mitigate environmental risks.

Landfills in India

- **Common Practice:** Landfilling is the predominant method of waste disposal in India, with over 3,100 landfills across the country.
- **Issues:** Poor management and rapid growth of landfills lead to environmental degradation and health hazards.
- **Magnitude of the Problem:** India generates over 62 million tonnes of municipal solid waste annually, with only 68 percent is collected, of which only 28 percent is treated.
- **Challenges:** Leachate contamination, air and water pollution, public health risks, and land scarcity are significant challenges associated with landfills in India.

Initiatives and Policies

- **Swachh Bharat Mission:** Government initiative aimed at achieving a clean and waste-free India by 2024, focusing on legacy waste management and landfill improvement.
- **Bio-mining and Waste-to-Energy:** Exploring technologies to extract resources and generate energy from landfill waste.
- **Extended Producer Responsibility (EPR):** Holding manufacturers accountable for product end-of-life management to reduce waste generation.

Future Outlook

- **Circular Economy:** Transitioning towards a circular economy model to minimize waste generation and promote reuse and recycling.
- **Public Awareness:** Educating the public on waste segregation and composting for sustainable waste management.

- **Government Support:** Continued support, private sector investment, and innovative solutions are vital for effective landfill management and waste reduction in India.
- **Landfill Fires:** Recent landfill fires, like in Kochi, highlight the need for Indian cities to prepare for summer incidents.

Causes of Fires

- **Unprocessed Waste:** Inefficient processing leads to prolonged presence of unprocessed waste in open landfills.
- **High Calorific Value:** Flammable materials like low-quality plastics contribute to elevated temperatures.
- **Hot Weather:** Dry and hot conditions increase waste flammability.

Impact of Fires

- **Air Pollution:** Releases harmful gases, causing respiratory problems and contributing to smog.
- **Groundwater Contamination:** Releases toxic chemicals, potentially harming aquatic ecosystems.
- **Soil Contamination:** Releases harmful chemicals, affecting plant growth and contaminating crops.
- **Economic Impact:** Results in cleanup costs and economic losses for local governments and businesses.
- Mitigation Strategies:
- **Permanent Solution:** Capping and closing landfills with soil, unsuitable for land reuse.
- **Bioremediation:** Clearing waste through a long-term bioremediation process.
- **Immediate Solution:** Site division, waste segregation, capping vulnerable areas, and ensuring proper waste disposal.

Way Forward

Implementing systematic waste processing, short-term preventive measures, and long-term solutions involving multiple stakeholders.

IGNITE YOUR MIND

From Landfill to Landfill? Imagine relying solely on landfills to dispose of all our waste, leading to land scarcity and potential environmental contamination. What are the limitations of landfills, and what alternative waste management strategies can we adopt?

2. Incineration

- Incineration involves the combustion of solid waste at high temperatures in specially designed facilities called incinerators.
- Waste is burned to generate heat, which is used to produce steam and drive turbines to generate electricity.
- Incineration reduces the volume of waste and can generate energy, but it also produces air emissions and ash residues that require proper management.

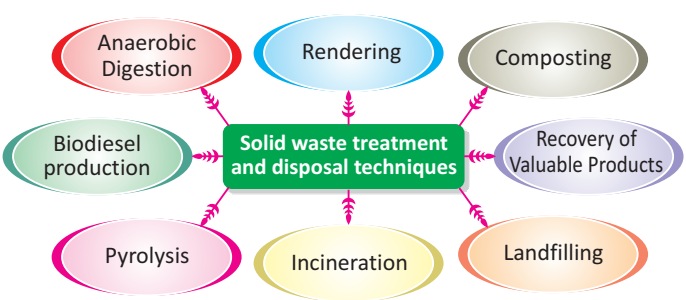


Fig. 10.9: Solid Waste Treatment and Disposal Techniques

- Advanced incineration technologies incorporate air pollution control devices to minimize emissions of pollutants such as particulate matter, nitrogen oxides, sulfur dioxide, and dioxins.

3. Recycling

- Recycling involves the collection, sorting, processing, and reprocessing of waste materials to produce new products.
- Waste materials such as paper, plastics, glass, metals, and electronics are collected and sorted for recycling.
- Recycling conserves natural resources, reduces energy consumption, and minimizes environmental impacts associated with the extraction and processing of raw materials.
- Recycling also creates economic opportunities, generates revenue, and reduces the need for landfill space.

IGNITE YOUR MIND

Beyond Recycling: While recycling is important, it's not a complete solution. What are the limitations of relying solely on recycling, and what other waste management approaches can be combined for a more sustainable system?

4. Composting

- Composting is the biological decomposition of organic waste materials such as food scraps, yard waste, and agricultural residues into nutrient-rich compost.

- Organic waste is collected and placed in composting bins or piles, where microorganisms break down the waste into compost through aerobic decomposition.
- Composting produces a valuable soil amendment that can improve soil fertility, structure, and water retention.
- Composting helps divert organic waste from landfills, reduces greenhouse gas emissions, and mitigates environmental pollution.

5. Waste-to-Energy (WtE)

- Waste materials are converted into energy through processes such as incineration, gasification, or anaerobic digestion.
- WTE facilities produce heat, electricity, or biofuels from waste, providing an alternative energy source while reducing the volume of waste sent to landfills.
- However, WTE can emit pollutants and requires proper emission control measures.
- **Examples:** Pyrolysis,Incineration and gasification.

6. Biological Treatment

- Waste materials are treated through biological processes such as anaerobic digestion, fermentation, or vermiculture.
- Anaerobic digestion breaks down organic waste in the absence of oxygen, producing biogas and digestate.
- Fermentation converts organic waste into biofuels or biochemicals, while vermiculture uses earthworms to decompose organic waste into nutrient-rich vermicompost.

Zero Liquid Discharge

Zero Liquid Discharge (ZLD) is a strategic wastewater treatment process where no liquid effluent is discharged at the end of the treatment cycle, thereby achieving complete recovery and reuse of water and minimizing environmental impact.

Mechanism

- In a ZLD system, all wastewater generated from industrial processes or other sources undergoes a series of treatment steps, including physical, chemical, and biological processes, to remove contaminants and recover water for reuse.
- The remaining solids and concentrated brine are further treated to extract any remaining water, leaving behind a solid residue or dry sludge.
- **The ZLD process** combines various **advanced treatment technologies** like:
  - **Membrane filtration (e.g., reverse osmosis):** Removes dissolved solids and contaminants.
  - **Evaporation:** Concentrates remaining liquid waste.
  - **Crystallization:** Separates solids from concentrated liquid.
  - **Drying and solidification:** Converts remaining solids into a manageable form (e.g., salt cake).

Benefits

- This approach helps industries **minimize water consumption, reduce pollution, and comply with environmental regulations** by **eliminating liquid discharge** into water bodies or the environment.
- ZLD systems are particularly beneficial in **water-scarce regions** or **industries where strict water quality standards must be met.**

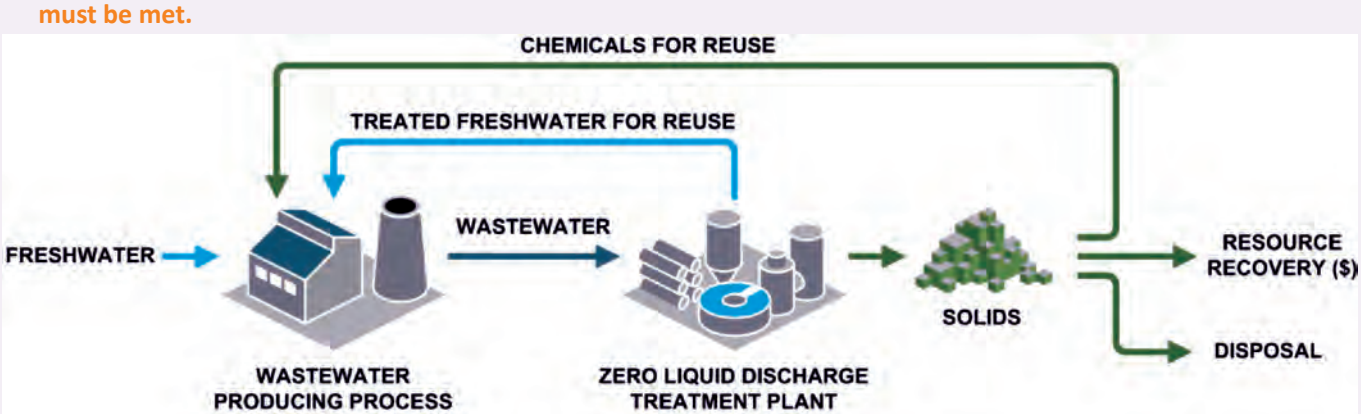


Fig. 10.10: Components of Zero Liquid Discharge

Role of Technology in Solid Waste Management

- **Waste Collection and Transportation:** Using GPS-enabled vehicles, route optimization software, and smart sensors to enhance collection efficiency and optimize waste transportation routes.

- **Waste Sorting and Recycling:** Deploying automated sorting systems, optical sorters, and robotics to streamline waste sorting processes and improve recycling rates.
- **Waste Treatment and Disposal:** Implementing advanced technologies such as anaerobic digestion, composting, and waste-to-energy to treat organic waste and generate renewable energy.
- **Data Management and Monitoring:** Utilizing data analytics, geographic information systems (GIS), and remote sensing technologies to monitor waste generation trends, optimize waste management strategies, and track progress towards sustainability goals.

Waste to Energy

Waste to Energy (WTE) is a process that involves converting various types of waste materials into usable forms of energy, such as **electricity, heat, or biofuels.** This conversion is typically achieved through **thermal, biological, or chemical processes.**

Mechanism of Waste to Energy Conversion

- **Collection and Segregation:** Waste materials are collected from households, industries, and other sources and transported to waste-to-energy facilities. At the facility, the waste is segregated to remove recyclable materials such as metals, plastics, and glass.
- **Pre-treatment:** Before undergoing conversion, the waste may undergo pre-treatment processes such as shredding, sorting, and drying to enhance the efficiency of energy recovery and reduce contaminants.
- **Combustion or Gasification:** Waste-to-energy technologies typically involve combustion or gasification processes to convert solid waste into energy.
  - In combustion, the waste is burned at **high temperatures** in a controlled environment, producing heat that is used to **generate steam.**
    - The **steam** drives turbines connected to **generators**, producing electricity.
  - **Gasification** involves heating the waste in a low-oxygen environment to produce a synthetic gas (syngas) containing carbon monoxide, hydrogen, and other gases.
    - The **syngas** is then combusted to generate heat or converted into other forms of energy such as hydrogen or biofuels.
- **Energy Recovery:** The heat generated from combustion or gasification is utilized to produce steam, which drives turbines or engines to generate electricity. Alternatively, the heat can be used directly for industrial processes, district heating, or other thermal applications.
- **Emissions Control:** Waste-to-energy facilities are equipped with emissions control systems to minimize air pollutants and environmental impacts. These systems include air pollution control devices such as **scrubbers, electrostatic precipitators, and selective catalytic reduction (SCR)** systems to remove **particulate matter, sulfur dioxide, nitrogen oxides, and other pollutants** from the flue gases.
- **Residue Management:** After energy recovery, the remaining ash and residues from the combustion or gasification process are collected and managed. Depending on the composition and characteristics, the ash may be recycled for use in construction materials or disposed of in landfill sites following regulatory guidelines.

IGNITE YOUR MIND

Waste to Wealth: Imagine transforming waste into a valuable resource, generating energy and reducing our reliance on landfills. What are the different waste-to-energy technologies, and what are the potential benefits and drawbacks of this approach?

Waste to Energy Conversion Technologies

- **Incineration:** This Involves burning waste at high temperatures in specially designed incinerators to produce heat, which is then used to generate steam and drive turbines to produce electricity.
- **Anaerobic Digestion:** Utilizes microorganisms to break down organic waste in the absence of oxygen, producing biogas (mainly methane) that can be used for electricity generation or as a renewable fuel.
- **Gasification:** Converts solid waste into synthetic gas (syngas) through high-temperature processes in the presence of limited oxygen, which can be used for electricity generation or as a feedstock for chemical production.
- **Pyrolysis:** Involves heating organic waste in the absence of oxygen to produce bio-oil, syngas, and char, which can be used for energy production or as raw materials for various applications.

These technologies offer a sustainable solution for waste management while generating renewable energy and reducing greenhouse gas emissions.

Benefits of Waste-to-Energy Conversion

- **Energy Recovery:** WTE facilities convert waste materials into energy in the form of electricity, heat, or biofuels. This energy can be used to power homes, businesses, and industries, reducing dependence on fossil fuels and contributing to energy security.

- **Waste Reduction:** WTE helps divert significant volumes of waste from landfills, thereby extending the lifespan of landfills and reducing the need for new landfill sites. By converting waste into energy, WTE facilities minimize the environmental impacts associated with landfilling, such as greenhouse gas emissions and leachate contamination.
- **Resource Conservation:** WTE facilitates the recovery of valuable resources from waste, such as metals, glass, and plastics, through combustion or gasification processes. These recovered materials can be recycled or reused, conserving natural resources and reducing the demand for virgin materials.

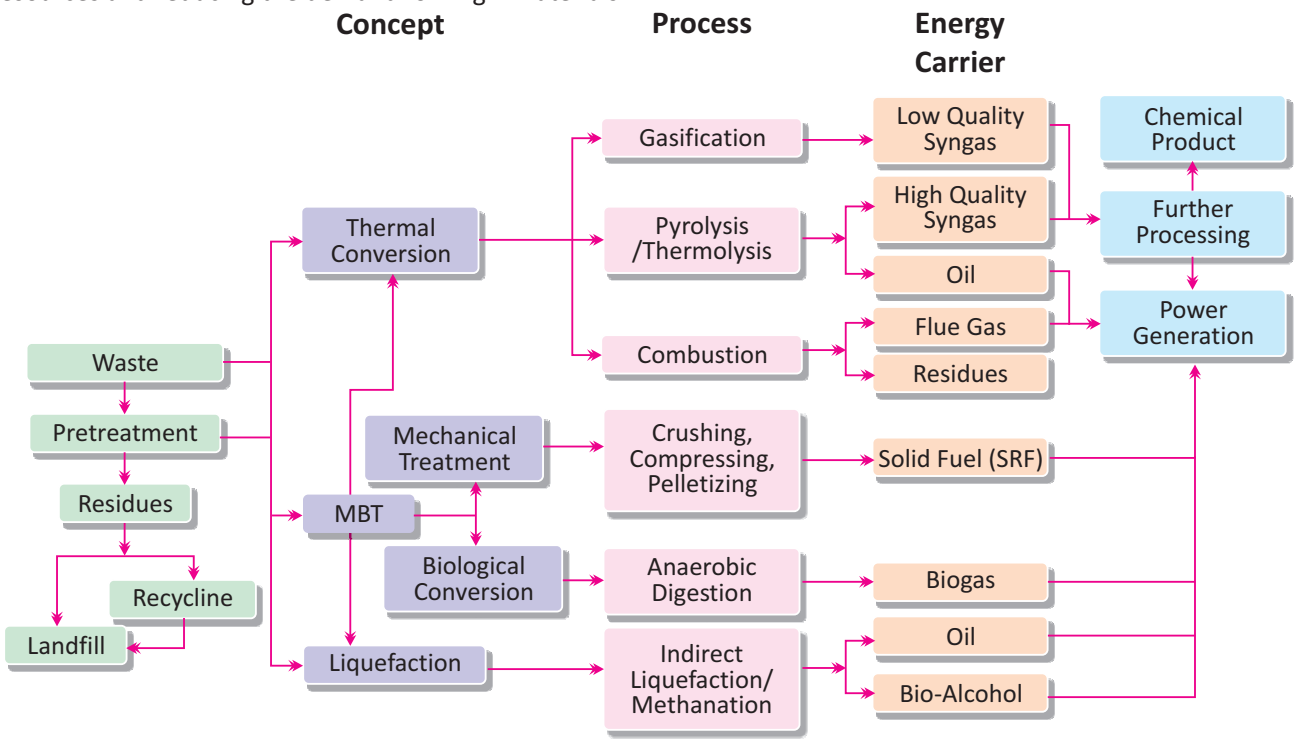


Fig. 10.11: Waste to Energy Process at Glance

- **Greenhouse Gas Reduction:** WTE helps mitigate climate change by reducing methane emissions from landfills, which are potent greenhouse gases. Combusting waste in WTE facilities generates lower greenhouse gas emissions compared to landfilling, making it a more environmentally sustainable waste management option.
- **Land Use Optimization:** WTE facilities require less land area compared to landfills, allowing for the reuse of land for other purposes such as recreation, agriculture, or urban development. By minimizing the footprint of waste disposal infrastructure, WTE contributes to efficient land use planning and urban sustainability.

Challenges in Using Waste-to-Energy Technologies

- **Air pollutants:** Incineration and other thermal conversion processes release air pollutants such as particulate matter, nitrogen oxides, sulphur dioxide, and dioxins, which can contribute to air pollution and impact human health and the environment.
- **Ash Management:** Incineration generates ash residues containing heavy metals and other contaminants, which require proper management to prevent environmental contamination and ensure safe disposal.
- **Greenhouse Gas Emissions:** While WtE facilities can reduce greenhouse gas emissions by displacing fossil fuels, they still emit carbon dioxide and other greenhouse gases during combustion, which contribute to climate change.
- **Resource Use:** WtE facilities require significant energy and resources for construction, operation, and maintenance, which can have environmental impacts and raise questions about the overall sustainability of the technology.

Steps Needed to Deal With Waste-to-Energy Technologies Challenges

- **Research and Development:** Invest in R&D to enhance the efficiency, reliability, and environmental performance of WTE technologies.
  - **Example:** IIT Delhi's low-cost biomass gasification technology for decentralized energy production in rural areas.
- **Waste Segregation and Pre-treatment:** Prioritize waste segregation at the source to separate recyclable and organic materials. Implement pre-treatment processes such as shredding and sorting to optimize feedstock quality for WTE facilities.
  - **Example:** Okhla waste-to-energy plant in Delhi equipped with advanced emissions control systems.

- **Integrated Waste Management:** Integrate WTE into comprehensive solid waste management systems focusing on waste reduction, recycling, and composting.
  - **Example:** Ghazipur waste-to-energy plant in Uttar Pradesh as part of an integrated solid waste management system by EDMC.

The "Indore Model" of Waste Management

- The **"Indore Model"** of waste management refers to the innovative waste management practices implemented in the city of Indore, Madhya Pradesh, India.
- The Indore Municipal Corporation (IMC) introduced this model to address the city's waste management challenges and promote sustainable waste practices.

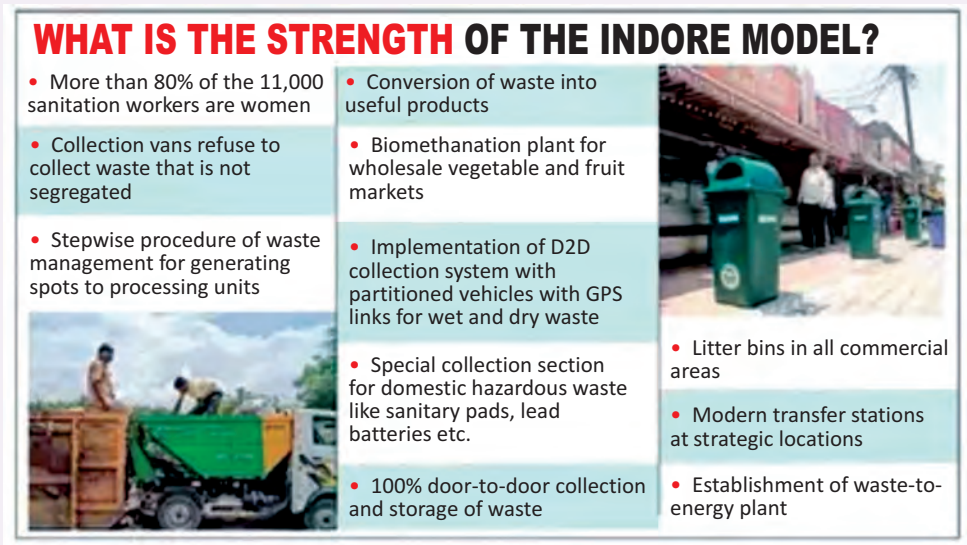

WHAT IS THE STRENGTH OF THE INDORE MODEL?
• More than 80% of the 11,000 sanitation workers are women
• Collection vans refuse to collect waste that is not segregated
• Stepwise procedure of waste management for generating spots to processing units
• Conversion of waste into useful products
• Biomethanation plant for wholesale vegetable and fruit markets
• Implementation of D2D collection system with partitioned vehicles with GPS links for wet and dry waste
• Special collection section for domestic hazardous waste like sanitary pads, lead batteries etc.
• 100% door-to-door collection and storage of waste
• Litter bins in all commercial areas
• Modern transfer stations at strategic locations
• Establishment of waste-to-energy plant

Fig. 10.12

- **Swachh Survekshan Survey 2024** ranks **Indore** as the **cleanest city in India in 2024.**
  - Indore has consistently held the top position for 7th time in a row.

Key Features of the Model

- **Segregation at Source:** Encourages residents to separate waste into categories like biodegradable, recyclables, and hazardous waste.
- **D2D Collection:** Implements systematic door-to-door collection of segregated waste using separate bins for different categories.
- **Material Recovery Facility (MRF):** Establishes facilities for sorting, processing, and recycling recyclable materials to maximize resource recovery.
- **Composting**: Processes biodegradable waste through composting facilities to produce organic compost for various purposes.
- **Public Awareness and Participation:** Conducts extensive public awareness campaigns and community participation initiatives to educate residents about waste segregation, recycling, and composting.
- **Enforcement and Monitoring:** Enforces strict regulations and penalties for non-compliance with waste management guidelines and conducts regular monitoring and inspection to ensure system efficiency.

IGNITE YOUR MIND

The Compost Revolution: Composting food scraps and yard waste can create nutrient-rich soil for gardens, reducing reliance on landfills and promoting sustainable practices. How can we encourage widespread adoption of composting at home and community levels?

Challenges in Solid Waste Management

- **Waste Generation:** Rapid urbanization, population growth, and changing consumption patterns contribute to increasing volumes of solid waste.

- **Waste Composition:** Diverse waste streams with varying compositions pose challenges for sorting, recycling, and disposal.
- **Infrastructure Deficiencies:** Inadequate waste collection, transportation, and disposal infrastructure in many areas leads to improper waste management practices.
- **Environmental Pollution:** Improper disposal of solid waste results in environmental pollution, including air and water pollution, soil contamination, and habitat degradation.
- **Health Risks:** Improperly managed solid waste can pose health risks to communities, including the spread of diseases and exposure to hazardous materials.
- **Social and Economic Impacts:** Inequities in waste management services, informal waste picking, and marginalized communities bearing the brunt of waste-related impacts contribute to social and economic challenges.

Global Initiatives for SWM

- **Global Alliance for Waste Management (GAWM):** Supported by the UN, this initiative encourages cooperation among governments, businesses, and NGOs in developing nations to enhance waste management practices, advocating for sustainable solutions and information exchange.
- **Clean Cities Coalition:** This international coalition of cities champions sustainable urban growth, promoting initiatives such as composting, extended producer responsibility programs, and waste-to-energy endeavors within waste management frameworks.
- **World Bank's What a Waste 2.0 Report:** Offering extensive insights, this report offers strategies and tools for addressing solid waste management issues, emphasizing waste reduction, recycling, and resource retrieval.

National Initiatives for SWM

Institutional Set-up

- The **Ministry of Environment Forest and Climate Change (MOEFCC),** along with its allied bodies such as the **Central Pollution Control Board (CPCB)** and **State Pollution Control Board (SPCB),** plays a pivotal role in India's solid waste management.
- The **Ministry of Housing and Urban Development** collaborates with **Urban Local Bodies (ULBs)** to constitute the key institutional framework overseeing solid waste management in the country.
- **Swachh Bharat Mission (Clean India Mission):** Launched in 2014, the Swachh Bharat Mission is a national cleanliness campaign aimed at achieving universal sanitation and cleanliness. The mission includes initiatives to promote waste segregation at source, the construction of household and community toilets, and the proper disposal of solid waste.
- **Solid Waste Management Rules:** The Ministry of Environment, Forest and Climate Change (MoEFCC) issued **Solid Waste Management Rules in 2016,** which lay down guidelines and regulations for the management of solid waste. The rules emphasize waste segregation, collection, transportation, processing, and disposal in an environmentally sound manner.

Legal Framework - Solid Waste Management Rules 2016

- The **Solid Waste Management Rules 2016** outline guidelines for waste separation into three categories by generators:
- **Wet (Biodegradable)**
- **Dry (Plastic, Paper, Metal, Wood, etc.)**
- **Domestic hazardous wastes** (e.g., **diapers, napkins, empty containers of cleaning agents, mosquito repellents, etc.**)
- Waste generators are mandated to hand over segregated waste to authorized rag-pickers, waste collectors, or local bodies.
- Waste generators are required to pay:
  - '**User Fee**' to waste collectors.
  - '**Spot Fine**' for littering and non-segregation.
- Used sanitary waste like **diapers** and **sanitary pads** should be securely wrapped in pouches provided by manufacturers or brand owners, or in suitable wrapping material. These should be placed in bins designated for **dry waste/non-biodegradable waste**.

- **Municipal Solid Waste Management (MSWM) Rules:** The MSWM Rules, notified in 2000 and revised in 2016, provide a framework for municipalities and urban local bodies to manage municipal solid waste effectively.
- **Waste-to-Energy Projects:** Several waste-to-energy projects have been initiated in India to convert municipal solid waste into energy through incineration or anaerobic digestion.
  - **Example: Delhi's Timarpur-Okhla Waste to Energy plant** is one of the largest waste-to-energy projects in India. The plant converts municipal solid waste into electricity, providing a sustainable solution for waste management while also contributing to renewable energy generation.
- **Innovative Technologies and Solutions:** Efforts are being made to adopt innovative technologies and solutions for solid waste management, such as decentralized waste processing units, waste-to-energy plants, biogas generation from organic waste, and recycling facilities.
  - **Example:** The city of **Surat** has implemented an innovative solution for managing construction and demolition waste.

- The **Waste to Wealth Portal** serves as a platform for the development and deployment of technologies aimed at **recycling materials** and generating valuable resources from waste. It aligns with the objectives of the government's **Science, Technology, Innovation, Advisory Council**.
- **Project REPLAN** explores innovative solutions, such as creating plastic carry bags by incorporating cotton fibre rags. This initiative addresses both **waste reduction** and **resource utilization**.
- **Swaccha Survekshan** seeks to enhance citizen participation in waste management and cleanliness. This behavioral change approach is essential for **sustainable waste management**.
  - The **Star Rating of Garbage-Free Cities** program encourages cities to enhance their cleanliness and waste management efforts. This performance-based assessment drives cities to compete and excel in waste management practices.
- Initiatives like the **Swachhata Hi Sewa Campaign**, **Compost Banao, Compost Apnao Campaign**, and the focused implementation of the **Plastic Waste Management Rules 2016** contribute to fostering a cleaner and more responsible waste management culture across the country.

Other Notable Initiatives:

Empowering Rural Women Through Waste Management:

- **Location:** The village of Gurala in Amritsar has introduced a pioneering Solid Waste Management Scheme with the primary objective of empowering rural women and promoting self-reliance.
- **Scheme Overview:** Inaugurated as a pilot project, the initiative aims to make women self-reliant by involving them in waste management activities within the village.
- **Self-Help Group (SHG):** To execute door-to-door garbage collection efficiently, a 10-member self-help group was established.
- **Financial Empowerment:** Each woman in the SHG receives a fixed monthly payment of Rs 3,000 from the village panchayat, and they also get share in the manure produced from the collected garbage.

National Policy on Faecal Sludge and Septage Management (FSSM-2017):

- **Objective:** The primary goal of the National Policy on Faecal Sludge and Septage Management is to facilitate the nationwide implementation of FSSM services in urban local bodies (ULBs).
- **Synergistic Approach:** The policy aligns with various Central Government programs such as the Swachh Bharat Mission (SBM), Atal Mission for Rejuvenation and Urban Transformation (AMRUT), and the Smart Cities Mission.
- **Gender Equality:** A significant focus of the policy is to reduce gender-based sanitation insecurity, health burdens, and promote gender-inclusive planning and design of sanitation infrastructure.

Transformation of Dumping Ground into Solid Waste Management Unit:

- **Project:** The SWACHAGRAH Project was launched with active collaboration from the private sector, where district authorities played a crucial role.
- **Community Participation:** The success of the initiative is attributed to local engagement, leading to the establishment of a Solid Waste Management (SWM) unit.
- **Achievements:** By May 2023, the SWM unit had sourced 10 tonnes of waste and successfully produced 1500 kg of compost.
- **Examples:**
- **Ahmedabad:** Ahmedabad implemented a waste segregation system at the household level. The city also corporates with private companies to collect waste and convert it into compost.
- **Surat:** Surat adopted a waste management system that uses bio-methanation and composting for organic waste.
- **Pune:** Pune introduced door-to-door waste collection, Material Recovery Facilities (MRFs) and waste-to-compost plants.
- **Bengaluru:** Bengaluru adopted a waste management system that involved segregation, composting and recycling of waste.
- **Chandigarh:** Chandigarh implemented a door-to-door waste collection system and promoted waste reduction, reuse and recycling.

4R Principle: Waste Reduction Strategy:

- **Reduce:** The strategy emphasizes minimizing resource usage to alleviate environmental impact.
- **Reuse:** Opting for rechargeable items over disposables is promoted to reduce unnecessary waste.
- **Recycle:** Encouraging the segregation of waste for proper disposal and supporting the use of recycled or green products.
- **Recovery or Reclaim:** The strategy advocates for the utilization of various systems and technologies to convert waste into new materials or energy, fostering sustainability and resourcefulness.

Way Forward

- **Waste Reduction:** Promoting waste reduction at the source through awareness campaigns, incentives, and regulations to minimize waste generation.
- **Source Segregation:** Encouraging households and businesses to segregate waste at the source to facilitate recycling and composting.

- **Community Engagement:** Engaging communities in waste management initiatives through participatory approaches, community-based organizations, and citizen participation.
- **Circular Economy:** Adopting circular economy principles to promote resource efficiency, material recovery, and product reuse and recycling.
- **Public-Private Partnerships (PPPs):** Collaborating with the private sector to improve waste management infrastructure, services, and technology deployment.
- **Innovative Financing:** Exploring innovative financing mechanisms, such as green bonds, carbon credits, and public-private partnerships, to fund sustainable waste management projects.

Effective solid waste management is crucial for environmental sustainability and public health. By tackling waste generation, improving infrastructure, raising awareness, and fostering collaboration, we can mitigate pollution and promote sustainable development.

PLASTIC WASTE

Plastic pollution is the accumulation of plastic objects and particles in the Earth's environment that adversely affects humans, wildlife and their habitat. Plastic pollution poses a significant threat to marine ecosystems due to its persistence, abundance, and harmful effects.

Types of Plastic Waste

Plastic waste can be classified into various types based on their chemical composition, use, and recyclability.

Based on Size

- **Macroplastics:** Large plastic debris typically visible to the naked eye, such as plastic bottles, bags, and packaging materials.
- **Mesoplastics:** Intermediate-sized plastic particles ranging from 5 millimeters to 1 micrometer, including fragments, pellets, and microplastics.
- **Microplastics:** Tiny plastic particles less than 5 millimeters in size, including microbeads, fibers, and microscopic fragments.

Based on Use

- **Single-Use Plastics:** Disposable plastic items designed for one-time use, such as plastic bags, straws, utensils, and packaging materials.
- **Durable Plastics:** Longer-lasting plastic products intended for multiple uses, such as plastic bottles, containers, and household items.
- **Industrial Plastics:** Specialized plastics used in manufacturing, construction, automotive, electronics, and other industrial applications.

Based on Recyclability

- **Recyclable Plastics:** Plastics that can be recycled and processed into new products or materials, including PET, HDPE, PP, and certain other plastics.
- **Non-Recyclable Plastics:** Plastics with limited or no recyclability due to composition, contamination, or lack of recycling infrastructure, such as PVC, PS, and mixed plastics.

Status of Plastic Waste

Global Level

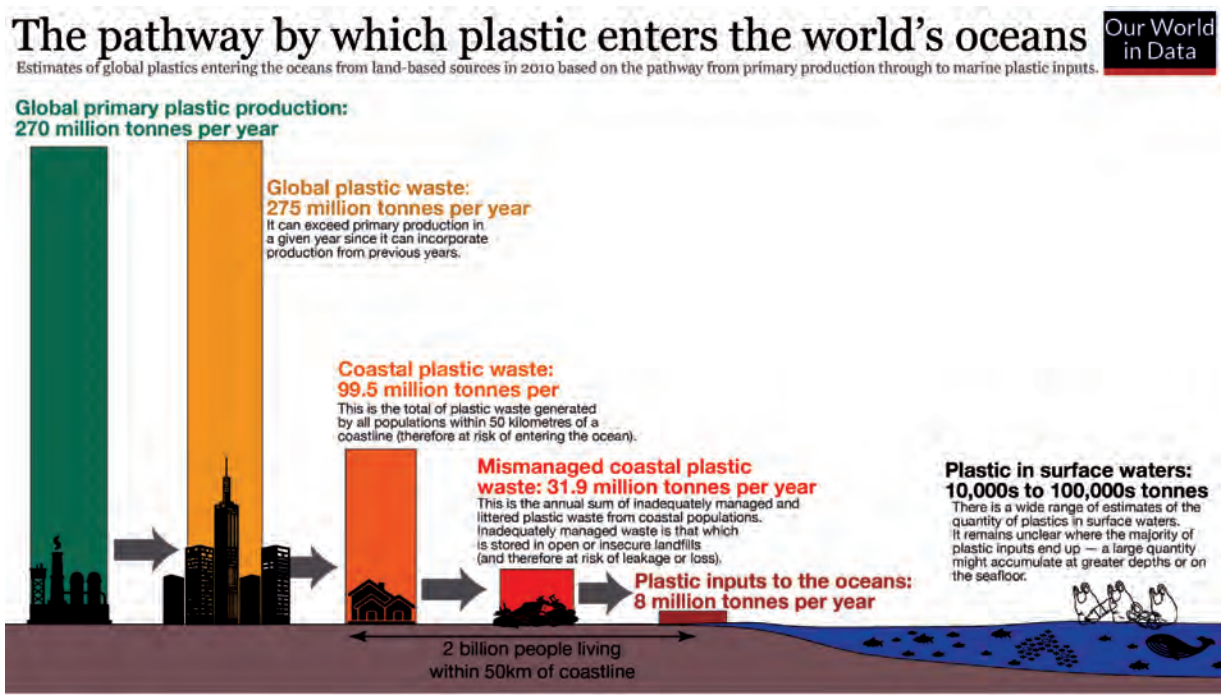

The pathway by which plastic enters the world's oceans
Estimates of global plastics entering the oceans from land-based sources in 2010 based on the pathway from primary production through to marine plastic inputs.
Our World in Data
Global primary plastic production: 270 million tonnes per year
Global plastic waste: 275 million tonnes per year
It can exceed primary production in a given year since it can incorporate production from previous years.
Coastal plastic waste: 99.5 million tonnes per
This is the total of plastic waste generated by all populations within 50 kilometres of a coastline (therefore at risk of entering the ocean).
Mismanaged coastal plastic waste: 31.9 million tonnes per year
This is the annual sum of inadequately managed and littered plastic waste from coastal populations. Inadequately managed waste is that which is stored in open or insecure landfills (and therefore at risk of leakage or loss).
Plastic inputs to the oceans: 8 million tonnes per year
Plastic in surface waters: 10,000s to 100,000s tonnes
There is a wide range of estimates of the quantity of plastics in surface waters. It remains unclear where the majority of plastic inputs end up — a large quantity might accumulate at greater depths or on the seafloor.
2 billion people living within 50km of coastline

Fig. 10.13: Global Estimates of Plastic Waste Entering Oceans

- The world produces 430 million tonnes of plastic annually, with two-thirds used briefly.
- Plastics comprise 85% of total marine waste, with plastic packaging representing 36% of plastic production.
- 46% of plastic waste is landfilled, 22% becomes litter, and only 15% is recycled, with less than 9% actually recycled after losses.
- Iceland has the highest per capita plastic consumption at 128.9 kg/person annually, 24.3 times higher than India's 5.3 kg/person.

India Level

- **Plastic Demand:** India's plastic demand **reached 22 million tonnes in 2023**, exceeding earlier projections. It is expected to **grow further to 25 million tonnes by 2025**, driven by factors like increasing urbanization and rising disposable incomes.
- **Plastic Production:** India's plastic production capacity **increased to 4.1 million tonnes in 2022-23**. However, the **actual production remained around 3.8 million tonnes**, due to fluctuations in demand and raw material prices.
- **Plastic Waste Generation:** India's plastic waste generation is estimated to have **reached 3.7 million tonnes in 2023 with low recycling rate of 30 %.** This is mainly due to the **increase in single-use plastic consumption** despite the ban.
- According to a report on Plastic Waste Management released by the **Ministry of Housing and Urban Affairs**, the **global average of plastic per capita consumption is 28 kg** and **India has a per capita plastic consumption of 11 kg.**

Sector Contribution to Plastic Waste

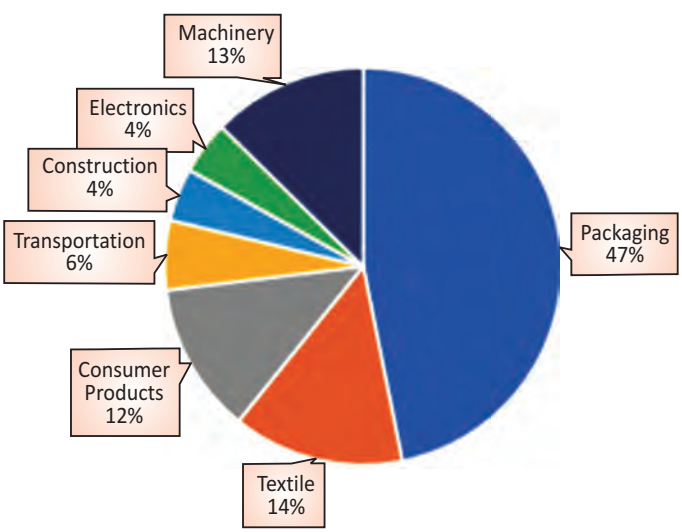


Fig. 10.14: Sectoral Contribution to Plastic Waste

- The Central Pollution Control Board (CPCB) Report (2019-20) states that **3.5 million metric tonnes** of plastic waste are generated in India annually.

Causes of Plastic Waste Accumulation

Causes of Plastic Pollution

- **Plastic Packaging:** Excessive use of plastic materials for product packaging.
- **Industrial and Commercial Practices:** Generation of plastic waste by industries and businesses.
- **Urbanization:** Rapid urban growth leads to increased plastic consumption and waste generation.
- **Illegal Dumping:** Improper disposal of plastic waste in unauthorized areas.
- **Inefficient Recycling:** Limited recycling facilities and low recycling rates.
- **Microplastics:** Breakdown of larger plastic items into minuscule particles.
- **Plastic in Waterways:** Pollution caused by plastic entering rivers, lakes, and oceans.
- **Plastic Littering:** Careless disposal of plastic waste in public spaces.
- **Disposable plastics overuse:** Excessive reliance on single-use plastics such as bags, bottles, and straws contributes significantly to plastic waste.
- **Inadequate waste management:** Many nations lack efficient systems for collecting, sorting, and recycling plastic waste, leading to its improper disposal in landfills or the environment.
- **Poor production practices:** Some plastic manufacturing processes produce microplastics, which contaminate water sources and harm wildlife.
- **Lack of accountability:** Weak regulations and enforcement fail to hold producers and consumers responsible for the plastic waste they generate, discouraging sustainable practices.
- **Limited public awareness:** Inadequate understanding of plastic's environmental and health impacts results in improper disposal and resistance to sustainable solutions, highlighting the need for public education.

IGNITE YOUR MIND

Plastic Planet: Picture a future where oceans are choked with plastic debris, harming marine life and disrupting entire ecosystems. How does our reliance on single-use plastics contribute to this problem, and what alternative solutions can we explore?

Consequences of Plastic Waste Accumulation

Ecological Consequences

- Plastic pollution adversely affects ecosystems, marine life, and terrestrial habitats. Marine animals often mistake plastic debris for food, leading to ingestion and entanglement, which can result in injury, suffocation, and death.

- **Plastic debris** can disrupt ecological balance by altering nutrient cycles, contaminating soil and water, and introducing harmful chemicals into the environment.
- **Microplastics**, tiny plastic particles, can accumulate in soil and water, posing risks to organisms at the base of the food chain and potentially bioaccumulating at higher trophic levels.

Plasticrusts

- **Plasticrusts** are a new type of plastic pollution in the form of plastic debris, covering rocks on intertidal shorelines which vary in thickness and color and are composed of polyethylene based on fourier-transform infrared spectroscopy (FTIR) analysis.
- They were first discovered on the South coast of the volcanic island of **Madeira** in the **Atlantic Ocean** in 2016 and have additionally been found on Giglio Island, Italy.
- They are considered a sub-type of **plastiglomerate** and could possibly have negative effects on surrounding fauna by entering the food web through consumption by benthic invertebrates.

Environmental Consequences

- Improper disposal of plastic waste, including open dumping and burning, releases toxic pollutants and greenhouse gases into the air, soil, and water, exacerbating air pollution and climate change.
- Plastic degradation and weathering can leach harmful chemicals, such as phthalates, bisphenol A (BPA), and persistent organic pollutants (POPs), into the environment, posing risks to human health and ecosystems.

Economic Consequences

- Plastic pollution imposes significant economic costs on society, including expenses for waste management, cleanup efforts, and environmental remediation.
- Tourism and recreation industries may suffer losses due to degraded landscapes, polluted beaches, and negative perceptions associated with plastic pollution.
- Fishing and maritime industries face risks from marine debris, including entanglement of gear, damage to vessels, and impacts on fishery resources, resulting in economic losses and livelihood challenges.
- **Transport of Invasive Species:** Plastic debris serves as a vector for the transportation of invasive species across ecosystems and geographic regions.

Social Consequences

- Plastic pollution poses risks to human health through exposure to hazardous chemicals leaching from plastic products and microplastics.
- Chemical additives in plastics, such as **phthalates** and **Bisphenol A(BPA)**, are associated with adverse health effects, including endocrine disruption, reproductive disorders, and developmental abnormalities.

*{**Phthalates** are a group of chemicals used to make plastics more durable. They are often called plasticizers. **Bisphenol A (BPA)** is a chemical produced in large quantities for use primarily in the production of polycarbonate plastics}*

- Microplastics can contaminate food and water supplies, potentially exposing humans to plastic particles and associated chemicals through ingestion, inhalation, and dermal contact.
- Studies have detected microplastics in various food items, drinking water sources, and even the air we breathe, raising concerns about potential health risks.

Microplastics

Microplastics are tiny plastic particles **less than 5 millimeters** in size, often invisible to the naked eye.

They can be categorized into:

- **Primary microplastics**, which are manufactured in small sizes for specific purposes such as **microbeads** in **cosmetics**.
- **Secondary microplastics**, which result from the breakdown of larger plastic debris in the environment.

Causes of Microplastics

- **Fragmentation:** Larger plastic items, such as bottles, bags, and packaging materials, degrade over time due to exposure to sunlight, wind, and wave action, breaking down into smaller fragments.
- **Abrasion:**Mechanical abrasion from natural forces, such as wave action, and anthropogenic activities, such as boat traffic and beach litter, can wear down plastic items into microplastic particles.
- **Release from Products:** Microbeads, fibres and nanoparticles used in personal care products, textiles, and industrial processes can be released into the environment during use and washing.

Consequences of Microplastics

- **Environmental Contamination:** Microplastics are pervasive pollutants in aquatic and terrestrial ecosystems, contaminating soil, water bodies, and sediments. They can accumulate in the environment, persist for long periods, and transport harmful chemicals and pathogens.
- **Impact on Marine Life:** Microplastics are ingested by marine organisms, including plankton, fish, seabirds, and marine mammals, causing physical harm, digestive blockages, and internal injuries. They can also bioaccumulate in the food chain, potentially reaching humans through seafood consumption.

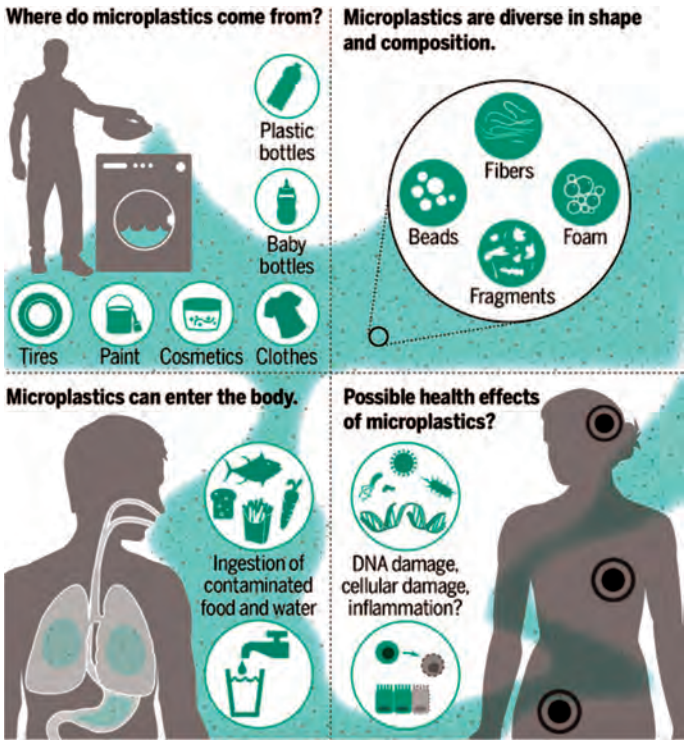


Fig. 10.15: Sources and Consequences of Microplastics

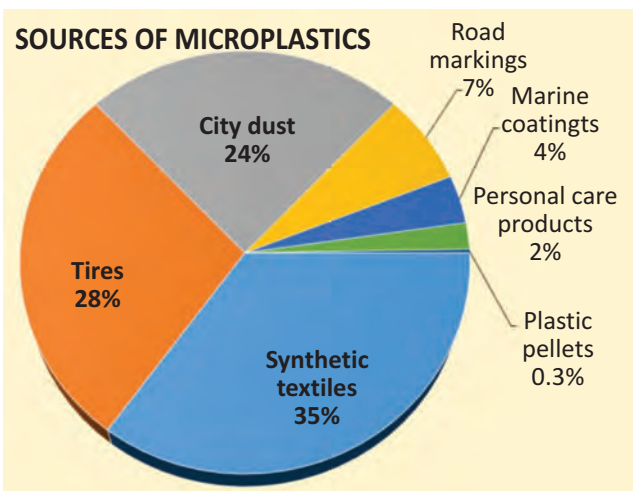


Fig. 10.16: Sources of Microplastics

- **Ecosystem Disruption:** Microplastics alter ecosystem dynamics and biogeochemical cycles, affecting nutrient cycling, microbial communities, and habitat structure. They may disrupt ecological interactions, such as predator-prey relationships and species diversity, leading to ecosystem instability and degradation.
- **Human Health Risks:** Microplastics pose potential risks to human health through ingestion, inhalation, and dermal contact. They may contain and absorb toxic chemicals, such as persistent organic pollutants (POPs) and heavy metals, which can leach into tissues and organs, potentially causing adverse health effects, including inflammation, oxidative stress, and reproductive disorders.

Way Forward

- **Regulatory Measures:** Implement regulations and policies to reduce the production, use, and release of microplastics into the environment. This may include bans or restrictions on microplastic ingredients in consumer products, such as personal care products and synthetic textiles.
  - **Example:** The **Bureau of Indian Standards** (BIS) has classified **microbeads** as "unsafe" for use in cosmetic products.
- **Waste Management:** Improve waste management infrastructure and practices to prevent the release of macroplastics that can degrade into microplastics. Implement measures to reduce plastic pollution at its source, such as promoting recycling, incentivizing the use of biodegradable materials, and enhancing litter clean-up efforts.
  - **Example:** Countries like **Sweden** have implemented advanced waste management systems that include efficient recycling and **waste-to-energy** plants, reducing the amount of plastic waste ending up in landfills or the environment.
- **Innovation and Alternatives:** Support the development and adoption of innovative technologies and alternative materials that are less harmful to the environment and human health. This includes bio-based plastics, biodegradable polymers, and eco-friendly packaging solutions as alternatives to conventional plastics.
  - **Example:** Indian startups like **Bakeys** are developing edible cutlery made from natural ingredients like sorghum, rice, and wheat. These innovative products offer alternatives to single-use plastic cutlery and help reduce plastic pollution in India.
- **Consumer Awareness and Behavior Change:** Raise public awareness about the impacts of microplastics and empower consumers to make informed choices. Promote sustainable consumption practices, such as opting for products with minimal or no plastic packaging, using reusable alternatives, and properly disposing of plastic waste.
  - **Example:** Campaigns such as **Plastic Free July** and **#BeatPlasticPollution by the United Nations Environment Programme (UNEP)** raise awareness about plastic pollution and encourage individuals to reduce their plastic consumption and waste.

PLASTIC WASTE MANAGEMENT

Plastic waste management involves the systematic handling, treatment, and disposal of plastic waste to minimize environmental pollution, conserve resources, and promote sustainability.

Plastic Waste Management Cycle

The plastic waste management cycle encompasses the various stages involved in the handling, treatment, and disposal of plastic waste to mitigate environmental impacts and promote sustainability.

Key Stages in the Plastic Waste Management Cycle

- **Generation:** The cycle begins with the generation of plastic waste, which includes various types of plastic materials used in packaging, consumer products, construction, and other industries. Plastic waste can be generated by households, businesses, industries, and institutions.
- **Collection:** After plastic waste is generated, it needs to be collected from its source. Collection methods may include curbside collection, drop-off points, recycling centres and informal waste pickers. Efficient collection systems are essential to prevent plastic waste from entering the environment and waterways.

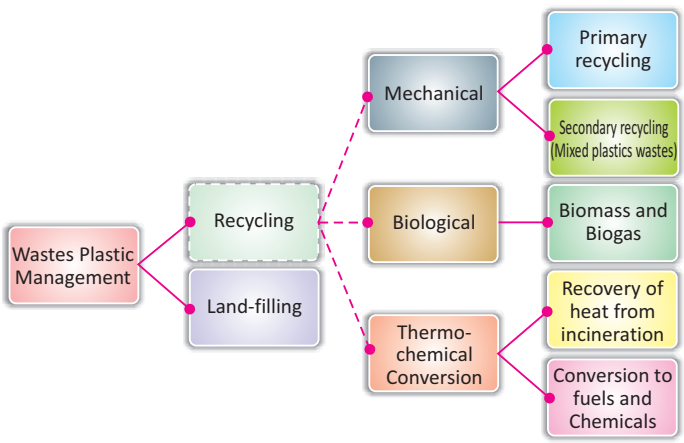


Fig.10.17: Plastic Waste Management

- **Sorting and Segregation:** Once collected, plastic waste undergoes sorting and segregation to separate different types of plastics based on their composition, color, and recyclability. Manual and automated sorting techniques are used to prepare plastic waste for recycling and other treatment processes.
- **Energy Recovery:** Plastic waste that cannot be recycled economically or feasibly may be used for energy recovery through processes such as waste-to-energy incineration or pyrolysis. These processes convert plastic waste into heat, electricity, or fuel, providing an alternative energy source while reducing the volume of waste sent to landfills.
- **Landfilling:** Plastic waste that cannot be recycled or recovered for energy may be disposed of in landfills. Proper landfilling practices are essential to prevent environmental pollution, groundwater contamination, and public health risks associated with plastic waste.
- **Recycling:** Recycling is a key component of plastic waste management, where plastic materials are processed and converted into new products or raw materials. Recycling processes may involve shredding, washing, melting, and extruding plastics to produce pellets, fibres or other recyclable materials. Recycled plastics can be used to manufacture a wide range of products, including packaging, textiles, furniture, and construction materials.

Challenges in Plastic Waste Management

- **Collection and Segregation:** Inadequate infrastructure and resources hinder efficient waste collection and segregation, particularly in rural areas. Mixed waste collection practices result in the contamination of recyclable plastics, reducing their usability.
- **Recycling and Processing:** Limited recycling capacity and outdated technology impede effective handling of diverse plastic types. Also Inefficient sorting and processing lead to the production of low-quality recycled plastics with limited applications.
- **Policy and Regulations:** Weak enforcement of plastic waste management regulations undermines their effectiveness.
- **Public Awareness and Behavior Change:** Preference for single-use plastics persists despite awareness campaigns, driven by convenience and affordability.
- **Technological and Economic Challenges:** High costs associated with advanced recycling technologies deter investment and adoption.
- **Single-Use Plastics:** Single-use plastics, such as disposable packaging, bottles, and utensils, contribute significantly to plastic waste generation. Reducing the consumption and production of single-use plastics is essential to mitigate plastic pollution and promote sustainable alternatives.

Global Initiatives in PWM

- **United Nations Environment Programme (UNEP) Clean Seas Campaign:** Launched in 2017, the Clean Seas campaign seeks to mobilize governments, businesses, and individuals to reduce plastic pollution in the world's oceans. The campaign focuses on raising awareness, promoting policy changes, and implementing solutions to prevent marine litter and protect marine ecosystems.
- **Plastic Pollution Coalition:** The Plastic Pollution Coalition is a global alliance of organizations, businesses, and individuals working to reduce plastic pollution and its impact on the environment and public health. The coalition advocates for policies to reduce plastic production, promote recycling and waste reduction, and support the transition to a circular economy.

- **Alliance to End Plastic Waste:** The Alliance to End Plastic Waste is a global partnership of companies from the plastics industry, governments, and NGOs working together to eliminate plastic waste in the environment. The alliance focuses on investing in infrastructure, innovation, education, and cleanup efforts to prevent plastic waste from entering the environment and promote a circular economy for plastics.
- **UNDP Plastic Waste Management (PWM) Programme (2018-2024):** The UNDP Plastic Waste Management (PWM) Programme (2018-2024) aimed to create a socio-technical model for transitioning plastic waste management from the informal to the formal economy in India.
  - Establish **Material Recovery Centres (Swachhta Kendras)** for sustainable waste management practices.
  - Institutionalize **waste pickers (Safai Sathis)** within the formal governance framework, improving their working conditions and social recognition.
  - Develop technology-supported knowledge management systems to ensure traceability, accountability, and digital governance throughout the waste value chain.
- **International Agreements:**
  - **The New Plastics Economy Global Commitment:** Led by the Ellen MacArthur Foundation and UN Environment Programme, aiming to eliminate plastic waste by 2040.
  - **Basel Convention Amendment on Plastic Waste:** Seeks to regulate international trade of plastic waste to prevent illegal dumping and promote responsible waste management.
- **Regional Collaborations:**
  - **European Union Plastics Strategy:** Aims for a circular economy for plastics by 2030, focusing on design, production, consumption, and waste management.
  - **African Union Single-Use Plastic Ban:** Implements a continental ban on single-use plastic bags, straws, and other items to reduce plastic pollution across Africa.
- **Specific Initiatives:**
  - **The Ocean Cleanup:** Develops and deploys technologies to remove plastic pollution from the oceans.
  - **Indonesia's National Action Plan on Marine Plastic Debris:** Aims to reduce marine plastic litter by 70% relative to business as usual by 2025.
  - **Break Free From Plastic:** Unites organizations globally to combat plastic pollution through campaigns, advocacy, and community action.
  - **The Alliance to End Plastic Waste:** A consortium of companies investing $1 billion in innovative solutions to eliminate plastic waste.
- **Investment and Innovation:**
  - **Circular Economy Funds:** Governments and organizations invest in circular economy initiatives, promoting recycling technologies and sustainable materials.
  - **Startups and Entrepreneurs:** Numerous startups develop solutions for plastic waste management, including bioplastics and plastic-to-fuel technologies.
- **London Convention and Protocol:** International agreements aimed at preventing marine pollution by controlling the dumping of waste and other matter into the world's seas and oceans.
  - The objective of the London Convention and Protocol is to promote the effective control of all sources of marine pollution. Contracting Parties shall take effective measures to prevent pollution of the marine environment caused by dumping at sea.

Plastic Overshoot Day

- On July 28, 2023, the Earth saw its first **Plastic Overshoot Day**: The point at which the **amount of plastic exceeds the global waste management capacity**, according to Swiss-based research consultancy Earth Action (EA).
- According to the report nearly 68,642,999 tonnes of additional plastic waste will end up in nature in 2023.
- **India** is among the **12 countries**, along with China, Brazil, Indonesia, Thailand, Russia, Mexico, the United States, Saudia Arabia, the Democratic Republic of Congo, Iran and Kazakhstan, which are responsible for **52 per cent** of the world's mismanaged plastic waste.
- Under current scenarios, despite pledges and increased waste management capacity, increased production of plastics will lead to global plastics pollution tripling by 2040.

National Initiatives for PWM in India

Plastic Waste Management Rules 2016

- The **Plastic Waste Management Rules (PWMR), 2016**, provide the statutory framework for plastic waste management in an environmentally sound manner throughout the country.
- The **Ministry of Environment, Forest and Climate Change** notified the **Plastic Waste Management Amendment Rules, 2021,** on August 12, 2021, prohibiting identified single use plastic items from July 1, 2022.
- The Ministry also notified the Guidelines on the **Extended Producer Responsibility** for plastic packaging vide Plastic Waste Management Amendment Rules, 2022, on February 16, 2022.

- **NITI Aayog's Plan:**
  - **MRF Model:** Public-private partnerships (PPPs) set up Material Recovery Facilities (MRFs) to sort, clean, and process plastic waste before recycling.
  - **Benefits:** Improved resource utilization, regulation compliance, and social inclusion of waste pickers through formalization.
  - **Examples:** Success stories from Indian cities showcase the model's potential.

Plastic Waste Management (Amendment) Rules 2022

- **Introduction of Extended Producer's Responsibility (EPR):** Holds producers accountable for environmentally sound management of plastic products throughout their life cycle.
- **Phase-out of Single-Use Plastics:**
  - Aims to eliminate single-use plastics from the economy.
  - Focuses on sustainable alternatives and responsible waste management practices.
- **New Provisions and Categories of Plastics:**
  - **Category 1:** Rigid plastic packaging.
  - **Category 2:** Flexible plastic packaging, plastic sheets, carry bags, sachets, or pouches.
  - **Category 3:** Multi-layered plastic packaging.
  - **Category 4:** Compostable plastic sheets and carry bags.
- **Plastic Packaging Regulations:**
  - **Mandatory Reuse:** Rigid plastic packaging material must be reused.
  - **Prescribed Recycling:** Minimum recycling levels enforced under EPR, promoting the use of recycled plastic content.
- **Extended Producer Responsibility (EPR):** It is the responsibility of a producer for the environmentally sound management of the product until the end of its life. EPR is a policy approach that holds producers, manufacturers, and importers accountable for the entire life cycle of their products, including post-consumer waste management. These rules introduce a **Market-Based Mechanism for the** sale and purchase of **surplus EPR certificates.**
- **EPR programs for plastic waste management typically involve:**
  - **Collection and Recycling Targets:** Producers are required to meet specific collection and recycling targets for the plastic products they place on the market, encouraging them to invest in recycling infrastructure and initiatives.
  - **Financial Contributions:** Producers may be required to contribute financially to support plastic waste collection, sorting, recycling, and disposal activities, helping to fund municipal recycling programs and incentivize waste management practices.
- **Product Design and Innovation:** Producers are encouraged to design products with recyclability in mind, using eco-friendly materials, minimizing packaging, and incorporating recycled content to reduce environmental impacts and promote circularity.
- **Centralized Online Portal:**
  - **CPCB-Controlled Portal:** Registration, return filing, and data repository.
  - Single-point access for **EPR implementation orders and guidelines.**
- **Environmental Compensation:**
  - **Polluter Pays Principle:** Levying compensation on those failing to meet EPR targets.
  - Contributes to improved environmental quality through **pollution prevention and control.**
- **Committee for Recommendations: CPCB-Constituted Committee** to recommend effective EPR implementation measures.
- **Annual Report on EPR Portal:** Reporting by **State Pollution Control Boards** and **Pollution Control Committees.**
- **Significance of the Guidelines:**
  - **Promoting Alternatives:** Encourages businesses to adopt sustainable packaging.
  - **Circular Economy Framework:** Strengthens a circular economy for plastic packaging waste.
  - **Reducing Pollution:** Addresses plastic waste littering and pollution.
  - **Environmental Protection:** Aligns with the UN Development **Programme's** focus on expanding plastic waste management in Indian cities.

IGNITE YOUR MIND

The Responsibility Chain: Who is responsible for managing the waste we generate? Explore the concept of Extended Producer Responsibility (EPR) and how it can incentivize producers to design products with responsible disposal in mind.

Ban on Single Use Plastic

- **Single-use plastics, or disposable plastics,** are used only once before they are thrown away or recycled.
- These items are things like **plastic bags, straws, coffee stirrers, soda and water bottles and most food packaging.**
  - **Up to 50%** of the plastics that we use are single-use.
- **India has banned manufacture, import, stocking, distribution, sale and use of identified single use plastic items,** which have low utility and high littering potential, all across the country from **July 1, 2022.**

Indentified Single Use Items Which are Banned Include

- Ear buds with plastic sticks
- Plastic sticks for balloons
- Plastic flags
- Candy sticks
- Ice-cream sticks
- Polystyrene (Thermocol) for decoration
- Plastic plates
- Cups, glasses, cutlery such as forks, spoons, knives, straw & trays
- Wrapping or packing films around sweet boxes
- Invitation cards
- Cigarette packets
- Plastic or PVC banners less than 100 micron, stirrers

India Plastics Pact

- Launched in 2021, the India Plastics Pact is an ambitious, collaborative initiative that brings together businesses, governments, and NGOs to tackle plastic waste challenges in India. It aims to transform the current linear plastic system into a circular economy by focusing on the "3 Rs": Reduce, Reuse, and Recycle.
- **Key objectives:** Define and eliminate problematic & unnecessary plastic packaging: Identify and phase out single-use plastics and other problematic packaging formats.
  - Achieve 100% recyclability or reusability of plastic packaging: Design and develop packaging that can be effectively recycled or reused within the Indian context.
  - Increase the average recycled content in plastic packaging to 25% by 2025: Promote the use of recycled plastic content in new packaging to reduce reliance on virgin plastics.
- **Functioning:** The Pact operates through a membership model, with businesses from various sectors joining and committing to achieving the set targets. Technical working groups are established to address specific challenges and develop solutions related to packaging design, recycling infrastructure, and consumer awareness.

IGNITE YOUR MIND

Waste-Free Events: Imagine organizing an event that generates minimal waste, using reusable materials and promoting responsible disposal practices. How can we plan and implement waste-free events to raise awareness and encourage sustainable choices?

Way Forward

- **Innovation:** Support research and development of innovative solutions to address plastic waste, such as biodegradable plastics, compostable packaging, and alternatives made from renewable resources. Encourage the adoption of sustainable materials and packaging designs that minimize environmental impact.
- **Policy Interventions:** Implement policies and regulations to hold businesses accountable for their plastic usage and waste management practices. This may include extended producer responsibility schemes, taxes or fees on single-use plastics, and incentives for eco-friendly alternatives.
- **International Cooperation:** Foster collaboration between governments, businesses, NGOs, and international organizations to develop coordinated strategies for addressing plastic waste on a global scale. Share best practices, knowledge, and resources to maximize impact and drive meaningful change.
- **Circular Economy Approach:** Shift towards a circular economy model where resources are used more efficiently, products are designed for durability and recyclability, and waste is minimized through reuse, recycling, and regeneration.
- **Consumer Behavior Change:** Encourage consumers to make sustainable choices by providing information, incentives, and alternatives to single-use plastics. Empower individuals to make a positive impact through their purchasing decisions and daily habits.

- **Beyond MRFs:**
  - **Complementary Models:** Explore reverse vending machines, deposit-refund schemes, and Extended Producer Responsibility (EPR) for diverse contexts and plastic types.
  - **Multi-Pronged Approach:** Combine MRFs with other models for comprehensive plastic waste management.
- **Deepening Impact:**
  - **Social Inclusion:** Integrate waste pickers, improve livelihoods, and ensure fair compensation.
  - **Sustainability:** Address challenges like limited capacity and informal practices. Promote innovation, infrastructure development, and strong enforcement.
- **Data & Research:** Include relevant data, research, and resources for further exploration.

3R Approach in Waste Management - Reduce, Reuse and Recycle

- **Reduce:** Encourage the reduction of plastic use at the source. This can be achieved through awareness campaigns, incentives for businesses to use alternative materials, and the implementation of plastic reduction policies such as bans on single-use plastics.
- **Reuse:** Promote the reuse of plastic products wherever possible. Encourage businesses to adopt reusable packaging and the consumers to use refillable containers for items like beverages and cleaning products.
- **Recycle:** Improve recycling infrastructure and accessibility to ensure that more plastic waste is recycled rather than ending up in landfills or oceans. Invest in advanced recycling technologies that can process a wider range of plastics and increase recycling rates.

Responsible Waste Management Hierachy

Fig. 10.18: Responsible Waste Management Hierarchy

IGNITE YOUR MIND

Art from Trash: Explore the scenario of using discarded materials like plastic bottles or electronic components to create art installations or functional objects. How can art serve as a powerful tool to raise awareness about waste issues and inspire creative solutions?

HAZARDOUS WASTE

Hazardous waste refers to any waste material that poses a substantial threat to human health, the environment, or both due to its chemical, biological, or physical characteristics. These wastes often require special handling, storage, and disposal methods to minimize risks to public health and the environment. Hazardous wastes can come from a variety of sources, including industrial processes, manufacturing, healthcare facilities, households, and agricultural activities.

Types

- **Listed Wastes:** These are wastes that are specifically listed as hazardous by regulatory agencies such as the **United States Environmental Protection Agency (EPA).**
  - **Examples:** include the **F-list** (wastes from common industrial processes), **K-list** (wastes from specific industries), and **P-list and U-list** (wastes from discarded commercial chemical products).
- **Characteristic Wastes:** These are wastes that exhibit one or more hazardous characteristics as defined by regulatory agencies.
- The **four** main characteristics are:
  - **Ignitability:** Wastes that are flammable or combustible, such as solvents and fuels.
  - **Corrosivity:** Wastes that are highly acidic or alkaline and can corrode containers, such as battery acid.
  - **Reactivity:** Wastes that are unstable, explosive, or reactive under certain conditions, such as peroxides and cyanides.
  - **Toxicity:** Wastes that contain toxic chemicals or heavy metals, such as lead, mercury, and arsenic.
  - **Mixed Wastes:** These are wastes that contain both hazardous and radioactive components, such as radioactive medical waste or contaminated laboratory materials.
- **Universal Wastes:** These are specific types of hazardous wastes that are widely generated by households and businesses and are subject to streamlined regulations for collection, recycling, and disposal.
  - **Examples:** include batteries, fluorescent bulbs, electronic devices, and certain pesticides.

- **Medical Wastes:** These are wastes generated from healthcare facilities, laboratories, and veterinary clinics that may contain infectious or biomedical materials, such as blood-soaked bandages, used needles, cultures, and pathological wastes.
- **Industrial Wastes:** These are wastes generated from industrial processes, manufacturing operations, and commercial activities, such as solvents, acids, bases, oils, paints, and chemical residues.
- **Radioactive Wastes:** These are wastes contaminated with radioactive materials from nuclear power plants, medical facilities, research laboratories, and other sources. Radioactive wastes can emit ionizing radiation and pose risks to human health and the environment.

Status

Global

- **Over 350 million tons** of hazardous waste was generated in the world in **2023**.
- The top **three** industry sectors that generated the most hazardous waste in 2021 were:
  - Basic Chemical Manufacturing
  - Petroleum and Coal Products Manufacturing
  - Waste Treatment and Disposal sector
- Almost **60 kg** of hazardous waste is generated a year **for every single person in the world** - and the amount is increasing.

India

- As per the **Central Pollution Control Board (CPCB)**, there are about 41,523 industries in the country generating about **7.90 million tonnes of hazardous waste annually**, out of which **landfillable waste** is about **3.32 million tonnes (42.02%), incinerable waste** is about **0.60 million tonnes (7.60%) and recyclable hazardous waste** is about **3.98 million tonnes (50.38%).**
  - **Gujarat** accounted for **more than one third** of the total hazardous waste output across India in 2022.
  - **Other major producers** included **Maharashtra, Andhra Pradesh, and Odisha.**

Causes of Hazardous Waste Accumulation

- **Industrial processes:**
  - **Manufacturing:** Chemical production, metal processing, electronics manufacturing, and other industries use hazardous materials that generate waste during production, cleaning, and maintenance.
  - **Energy production:** Coal-fired power plants generate fly ash and other hazardous byproducts, while oil and gas extraction produces hazardous waste like drilling mud and fracking fluids.
  - **Mining and refining:** Extracting and processing minerals like lead, mercury, and arsenic generates hazardous waste in the form of tailings and processing residues.
- **Consumer products:**
  - **Household items:** Products like batteries, paints, pesticides, cleaning chemicals, and pharmaceuticals often contain hazardous substances that become waste after use.
  - **E-waste:** Electronic devices contain various hazardous materials like lead, mercury, and flame retardants, posing a challenge when discarded.
  - **Agriculture:** Farmers use pesticides, herbicides, and fertilizers, some of which can be hazardous and generate waste during application and storage.
- **Healthcare facilities:**
  - **Medical waste:** Hospitals and clinics generate infectious waste, pharmaceutical waste, and sharps (needles and syringes) needing special handling and disposal due to their hazardous nature.
  - **Laboratory waste:** Research facilities and laboratories use various hazardous chemicals and generate waste requiring proper treatment and disposal.
- **Other factors:**
  - **Accidental spills and leaks:** Industrial accidents, transportation spills, and improper handling of hazardous materials can lead to uncontrolled waste generation.
  - **Lack of awareness and infrastructure:** Limited knowledge about proper handling and disposal practices, combined with inadequate infrastructure, can contribute to hazardous waste accumulation.

Consequences of Hazardous Waste Accumulation

- **Environmental Damage:**
  - **Water Contamination:** 80% of untreated industrial wastewater globally contributes to water contamination, causing over 485,000 annual diarrheal deaths.
  - **Soil Contamination:** Hazardous waste, especially lead, is linked to 1.03 million global deaths annually.
- **Public Health Risks:**
  - **Direct Exposure:** Living near hazardous waste sites increases cancer risk by 22%.
  - **Bioaccumulation:** Mercury in fish poses developmental risks to exposed children.
- **Economic Costs:**
  - **Clean-up Efforts:** Cleaning up a Superfund site costs an average of $30 million.
  - **Reduced Agricultural Productivity:** Lead-contaminated soil reduces crop yields by up to 50%.
- **Social Issues:**
  - **Environmental Injustice:** Communities with more people of color are three times more likely to have hazardous waste facilities within a one-mile radius.

- **Loss of Livelihoods:** Lead-contaminated fisheries result in annual economic losses of up to $2 billion in low- and middle-income countries.

❑ These consequences paint a sobering picture of the widespread consequences of hazardous waste accumulation. By acknowledging the gravity of the situation and taking action, we can work towards a healthier future for all.

HAZARDOUS WASTE MANAGEMENT

Hazardous waste management refers to the **systematic handling, treatment, disposal, and regulation of hazardous waste materials** that pose significant risks to human health, the environment, and ecosystems due to their toxic, flammable, corrosive, or reactive properties.

The goal of hazardous waste management is to **minimize the generation of hazardous waste, mitigate environmental pollution, protect public health, and ensure compliance with regulatory requirements.**

Hazardous Waste Management Cycle

The Hazardous Waste Management Cycle involves several key stages:

❑ **Generation:** The first stage involves the generation of hazardous waste from various sources such as industrial processes, consumer products, healthcare facilities, and agricultural activities.
- Waste is classified as hazardous based on its chemical, physical, and biological properties.

❑ **Identification and Characterization:** Hazardous wastes are identified and characterized to determine their composition, properties, and potential risks to human health and the environment.
- This involves testing, sampling, and analysis to classify wastes according to regulatory criteria.

❑ **Storage:** Hazardous wastes are stored temporarily at designated facilities or storage areas before treatment, recycling, or disposal.
- Storage facilities must comply with safety regulations to prevent spills, leaks, and environmental contamination.

❑ **Transportation:** Hazardous wastes are transported from generation sites to treatment, recycling, or disposal facilities using specialized vehicles and containers.

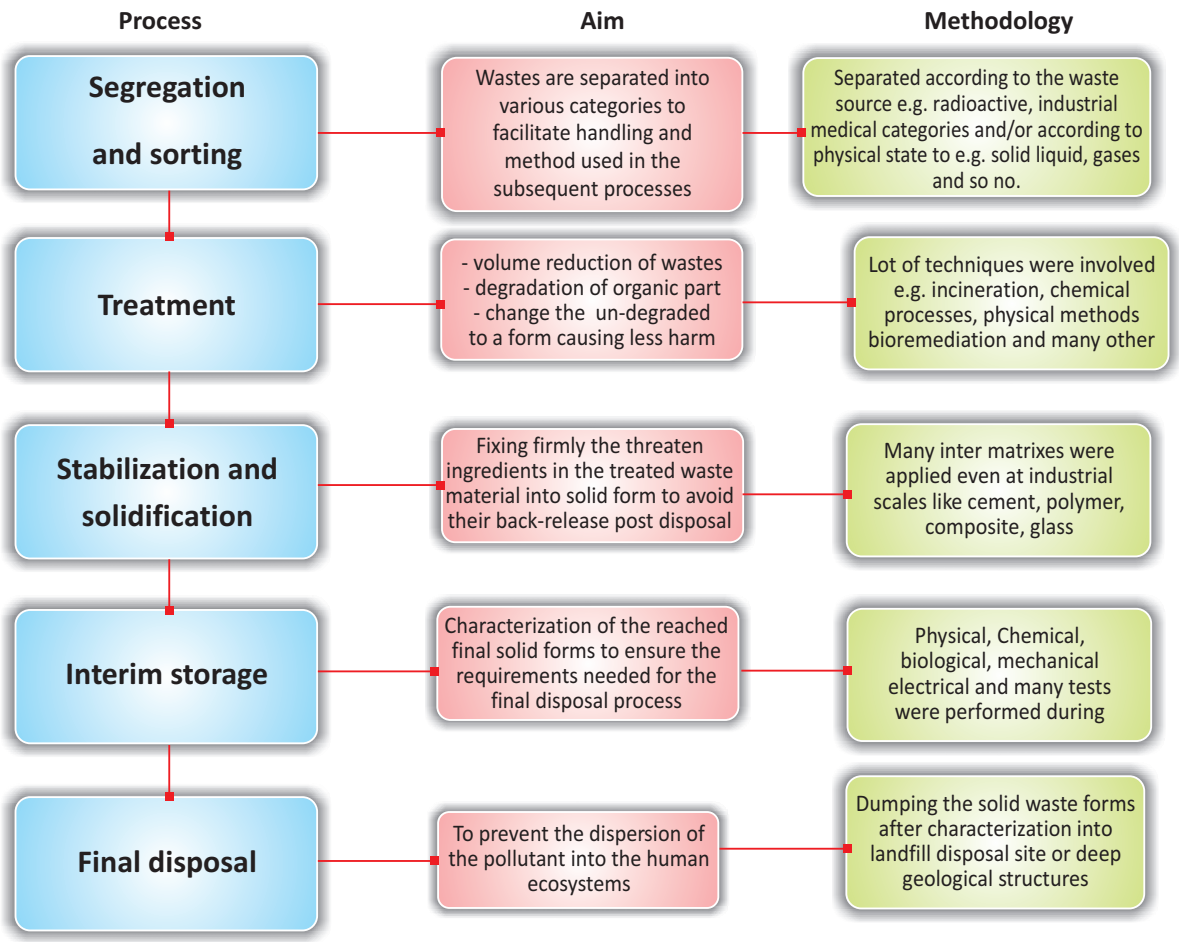

Process
Aim
Methodology
Segregation and sorting
Wastes are separated into various categories to facilitate handling and method used in the subsequent processes
Separated according to the waste source e.g. radioactive, industrial medical categories and/or according to physical state to e.g. solid liquid, gases and so no.
Treatment
- volume reduction of wastes
- degradation of organic part
- change the un-degraded to a form causing less harm
Lot of techniques were involved e.g. incineration, chemical processes, physical methods bioremediation and many other
Stabilization and solidification
Fixing firmly the threaten ingredients in the treated waste material into solid form to avoid their back-release post disposal
Many inter matrixes were applied even at industrial scales like cement, polymer, composite, glass
Interim storage
Characterization of the reached final solid forms to ensure the requirements needed for the final disposal process
Physical, Chemical, biological, mechanical electrical and many tests were performed during
Final disposal
To prevent the dispersion of the pollutant into the human ecosystems
Dumping the solid waste forms after characterization into landfill disposal site or deep geological structures

Fig.10.19: Hazardous Waste Management Cycle

- Transport activities must adhere to strict regulations for packaging, labeling, handling, and documentation to ensure safety and regulatory compliance.

- **Treatment:** Hazardous wastes undergo treatment processes to reduce their toxicity, volume, or environmental impact.
  - Treatment methods may include physical, chemical, and biological processes such as incineration, neutralization, oxidation, precipitation, filtration, and biodegradation.
- **Recycling and Recovery:** Where feasible, hazardous wastes are recycled or recovered to extract valuable materials for reuse or energy recovery.
  - Recycling reduces the need for virgin resources, conserves energy, and minimizes environmental pollution associated with waste disposal.
- **Disposal:** Hazardous wastes that cannot be treated, recycled, or recovered are disposed of in approved facilities designed to contain and isolate hazardous materials from the environment.
  - Disposal methods include secure landfills, deep injection wells, and other engineered containment systems.
- **Monitoring and Compliance:** Throughout the hazardous waste management cycle, monitoring and compliance activities are conducted to ensure that waste handling, treatment, and disposal practices meet regulatory requirements.
  - This involves inspections, sampling, reporting, and enforcement to prevent pollution and protect public health and the environment.

Measures to Control Hazardous Wastes

Global Initiatives

Basel Convention

- The **Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal** is an international treaty aimed at reducing the transboundary movement of hazardous wastes and ensuring environmentally sound management of such wastes.
- It regulates the export and import of hazardous wastes and promotes their minimization, recycling, and disposal in an environmentally sound manner.
- Adopted in **1989**, the convention aims to minimize the generation of hazardous wastes, promote their safe disposal, and prevent illegal dumping in developing countries.
- Key provisions of the Basel Convention include:
  - The establishment of a prior informed consent procedure for the export and import of hazardous wastes
  - The promotion of environmentally sound waste management practices
  - The development of guidelines for the transboundary movement of hazardous wastes.
- **India is a party to the Basel Convention** and has committed to regulating the transboundary movement of hazardous wastes and ensuring their environmentally sound management.

Rotterdam Convention

- The Rotterdam Convention, adopted in 1998, on the **Prior Informed Consent** Procedure for Certain Hazardous Chemicals and Pesticides in International Trade is an international treaty established to promote shared responsibility and cooperation in the international trade of hazardous chemicals and pesticides.
- **Key provisions of the Rotterdam Convention include:**
  - The establishment of a prior informed consent procedure for the import and export of hazardous chemicals and pesticides
  - the promotion of labeling and safety data sheets
  - the exchange of information among participating countries
- **India is a party to the Rotterdam Convention** and has committed to promoting shared responsibility and cooperation in the international trade of hazardous chemicals and pesticides.
- India complies with the provisions of the convention by **participating in the exchange of information on hazardous chemicals, promoting informed decision-making by importing countries, and ensuring the safe handling and use of these substances.**

Stockholm Convention

- **The Stockholm Convention on Persistent Organic Pollutants (POPs)** is a global treaty aimed at protecting human health and the environment from the adverse effects of POPs, which are highly toxic, persistent, and bioaccumulative substances that can travel long distances through air and water currents. It was adopted in **2001** and entered into force in **2004**, the convention aims to eliminate or restrict the production, use, and release of POPs into the environment.
- **Key provisions of the Stockholm Convention include:**
  - The listing of POPs under Annexes A, B, and C, which specify control measures such as bans, restrictions, and phase-outs.
  - The promotion of alternatives and best available techniques to reduce POPs emissions and exposure.
- **India is a party to the Stockholm Convention on Persistent Organic Pollutants (POPs)** and has committed to protecting human health and the environment from the adverse effects of POPs.

- **India has listed POPs under Annexes A, B, and C of the convention** and has taken steps to reduce emissions and exposure to POPs through regulatory measures, technological interventions, and public awareness campaigns.

United Nations Sustainable Development Goals (SDGs)

- The SDGs include targets related to sustainable waste management, pollution prevention, and environmental protection.
- **Goal 12 (Responsible Consumption and Production)** specifically calls for the reduction of hazardous waste generation through sustainable practices and the promotion of environmentally sound waste management.

National Initiatives

The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016

- These rules regulate the generation, storage, transportation, treatment, and disposal of hazardous wastes in India.
- They require waste generators to take measures for the safe handling, treatment, and disposal of hazardous wastes and mandate the establishment of treatment, storage, and disposal facilities.

National Hazardous Waste Information System(NHWIS)

- It is a **web based system**, which has been developed by the **Ministry of Environment,Forests and Climate Change** to provide the status of hazardous waste management in the country.
- It is a **GIS based** information system.
- The database available on the web is regularly updated by all **State Pollution Control Boards** to facilitate evidence based planning.

Integrated Waste Management Facilities

- The government of India has encouraged the development of integrated waste management facilities, including hazardous waste treatment, storage, and disposal facilities (TSDFs). These facilities are designed to safely handle and manage hazardous wastes in compliance with environmental regulations.
  - **Example: Ramky Enviro Engineers Limited** set up **India's first integrated industrial hazardous waste management facility** in **Hyderabad,Telangana.**

Swachh Bharat Mission (SBM) Urban 2.0

- The Swachh Bharat Mission (SBM) Urban 2.0 is a revamped version of the Swachh Bharat Mission, which aims to ensure cleanliness and sanitation in urban areas across India.
  - One of the key objectives of SBM Urban 2.0 is to achieve **100% waste processing by 2026,** which includes the **management of hazardous waste** generated from healthcare facilities and industrial units.

Promotion of waste-to-energy technologies

- The government encourages technologies like incineration and gasification to convert some hazardous waste into energy, minimizing landfill dependence.
  - **Example: Biomedical Waste Incineration Plants (BMWIPs)** were established to manage **hazardous waste** from **healthcare facilities.**
    - By incinerating hazardous waste, BMWIPs not only eliminate pathogens and reduce the volume of waste but also generate heat energy that can be used for various purposes, such as steam generation or electricity production.

Challenges in Measures to Control Hazardous Wastes

1. **Lack of Awareness and Compliance:** Non-compliance with existing regulations due to weak enforcement or insufficient incentives exacerbates the problems.
   - A 2021 study by CPCB revealed that **only 30%** of healthcare facilities in India complied with biomedical waste management regulations.
2. **Inadequate Infrastructure and Capacity:** Shortage of treatment and disposal facilities for various types of hazardous waste, leading to improper disposal and environmental contamination.
   - The Ministry of Environment, Forests & Climate Change estimates India only has around 1,800 operational treatment, storage and disposal facilities (TSDFs), while the requirement is estimated to be around 3,800.
3. **Informal Sector Involvement:** Significant involvement of informal waste pickers in hazardous waste collection, often poses health risks and environmental concerns due to unsafe practices.
   - There are approximately **4 million** informal waste pickers dealing with hazardous waste in India.
4. **Cost and Technology:** Implementing safe and environmentally sound hazardous waste management technologies can be expensive, especially for small and medium-sized enterprises.
   - According to FICCI, setting up a hazardous waste incinerator in India costs **₹20-30 crore**, posing a challenge for small businesses.
5. **Illegal Transboundary Movement:** Illegal transboundary movement of hazardous waste poses a serious threat, requiring stricter regulations and international cooperation for control.
   - **Example:** In 2019, 38 containers of hazardous and contaminated waste from the US were smuggled through the Mundra port into India.

- As per the **Basel Convention**,ratified by India,such illegal containers must be sent back to their **countries of origin.**

6. **Public Perception and NIMBYism: NIMBYism (Not In My Backyard) attitudes** towards hazardous waste facilities are reported worldwide, which hinders the setting up and operation of waste treatment facilities near large populations.

Way Forward

1. **Strengthening the Foundation:**
   - **Enhanced Regulation and Enforcement:** Revise and strengthen hazardous waste regulations, ensuring clarity, stricter enforcement mechanisms, and penalties for non-compliance.
     - **Example:** The **European Union's REACH regulation** sets stringent standards for chemicals and promotes safer alternatives, serving as a model for other countries.

*{**REACH** is a European Regulation and is an acronym for the **Registration, Evaluation, Authorisation and Restriction of Chemicals**}*

   - **Capacity Building:** Invest in developing infrastructure for treatment and disposal facilities, train personnel in safe handling practices, and promote technology transfer to developing countries.
   - **Public Awareness and Education:** Launch awareness campaigns targeting industries, communities, and individuals, emphasizing responsible waste generation, segregation, and disposal practices.
2. **Embracing Innovation and Collaboration:**
   - **Advance Technology Adoption:** Encourage research and development of innovative, sustainable, and cost-effective technologies for hazardous waste treatment and resource recovery.
   - **Cross-Sector Collaboration:** Foster collaboration between government, industry, academia, and NGOs to share best practices, leverage expertise, and develop joint solutions.
   - **International Cooperation:** Strengthen international agreements on transboundary waste movement, promote technology transfer, and facilitate knowledge-sharing between nations.
     - **Example:** The **Basel Convention's Technical Cooperation Assistance Programme** facilitates knowledge-sharing and technology transfer for developing countries.
3. **Fostering Sustainability and Responsibility:**
   - **Extended Producer Responsibility (EPR):** Implement EPR schemes, holding manufacturers accountable for the collection, treatment, and disposal of their products throughout their lifecycle.
   - **Economic Incentives:** Design economic instruments like pollution taxes and subsidies to encourage responsible waste management practices and discourage illegal dumping.
   - **Community Engagement:** Actively involve local communities in decision-making processes, address concerns through transparent communication, and build trust through capacity-building initiatives.

Pfand System in Germany

- **Pfand System** in Germany, is a bottle return system. When you buy certain products, you pay a deposit, called 'Pfand' for the container. When you return the empty container, you get your deposit back. The empty bottles are recycled or reused.
- This incentivizes **return and recycling**, thereby achieving **high recycling rates.**

4. **Addressing Emerging Challenges:**
   - **Research and Development:** Invest in research on emerging hazardous waste streams like e-waste and pharmaceutical waste, developing safe and effective management strategies.
   - **Adaptation and Flexibility:** Regularly review regulations and policies to adapt to evolving technologies, waste streams, and international standards.
   - **Continuous Improvement:** Foster a culture of continuous learning and improvement within industries, regulatory bodies, and waste management systems.

By adopting a multi-faceted approach that integrates regulatory, educational, technological, and collaborative strategies, countries can effectively manage hazardous wastes, minimize environmental pollution, protect public health, and promote sustainable development.

E-WASTE

E-waste, or electronic waste, refers to discarded electrical or electronic devices that have reached the end of their useful life. These devices may include computers, laptops, smartphones, tablets, televisions, refrigerators, washing machines, and other consumer electronics.

Types of E-Waste

- **Computers:** Including desktops, laptops, and peripherals such as keyboards, mice, and monitors.
- **Consumer Electronics:** Such as televisions, DVD players, gaming consoles, cameras, and audio equipment.

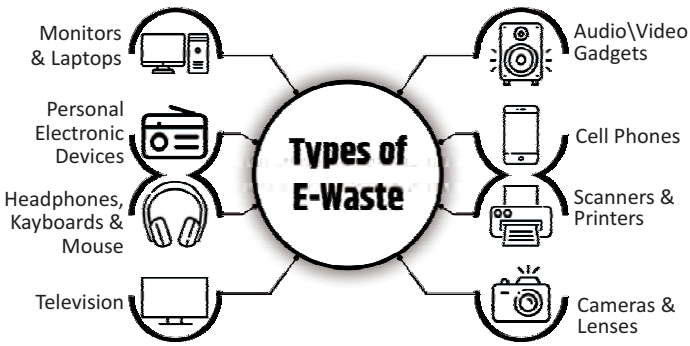


Fig. 10.20: Types of E-Waste

- **Mobile Devices:** Including smartphones, tablets, and accessories like chargers and headphones.
- **Home Appliances:** Such as refrigerators, washing machines, microwaves, and air conditioners.
- **Office Equipment:** Including printers, scanners, fax machines, and photocopiers.
- **Medical Devices:** Such as monitoring equipment, imaging devices, and diagnostic tools.
- **IT and Telecommunication Equipment:** Such as servers, routers, switches, and telecom infrastructure components.

Electronic Waste Components

- **Metals:** E-waste contains metals such as **aluminum, copper, iron, and steel,** which can be recovered and recycled for reuse in manufacturing processes.

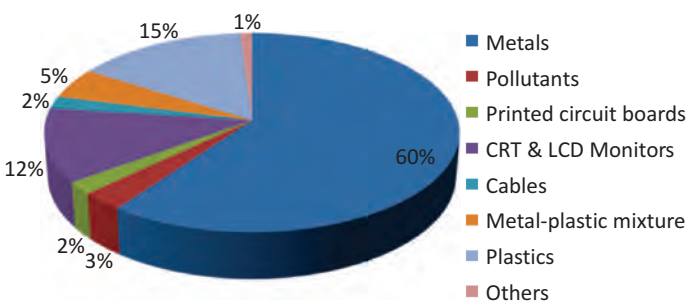


Fig. 10.21: Components of E-Waste

- **Cathode ray tubes (CRTs): Cathode ray tubes (CRTs)** in old televisions and monitors contain **leaded glass**, which poses environmental and health risks if not properly handled and disposed of.
- **Plastics:** E-waste often contains **plastic casings, cables, and other components,** which can be difficult to recycle and may release harmful chemicals when incinerated.
- **Printed circuit boards (PCBs): Printed circuit boards (PCBs)** contain valuable metals like **gold, silver, and copper,** as well as hazardous substances like **lead, mercury, and brominated flame retardants.**
- **Metal-plastic mixture:** These mixtures typically arise from the housing, casing, or enclosures of electronic devices, where metals and plastics are combined to form composite materials.

Common Pollutants Found in E-Waste

- **Heavy Metals:** E-waste often contains heavy metals such as lead, mercury, cadmium, and chromium, which are toxic to humans and ecosystems. These metals can leach into soil and water sources, leading to contamination and adverse health effects.
- **Brominated Flame Retardants (BFRs):** BFRs are chemicals added to electronic devices to reduce their flammability. However, BFRs can persist in the environment and bioaccumulate in organisms, posing risks to human health and wildlife.
- **Polychlorinated Biphenyls (PCBs):** PCBs are organic pollutants found in older electronic devices, such as capacitors and transformers. PCBs are persistent in the environment and can cause adverse health effects, including cancer and reproductive disorders.
- **Dioxins and Furans:** These are toxic byproducts of incomplete combustion and are often produced during the incineration of e-waste. Dioxins and furans are highly persistent and bioaccumulate in the food chain, posing serious health risks to humans and wildlife.
- **Polyvinyl Chloride (PVC):** PVC is a common plastic used in electronic devices, particularly cables and wiring. When PVC is burned or incinerated, it releases harmful chemicals such as dioxins and hydrogen chloride into the air.
- **Polycyclic Aromatic Hydrocarbons (PAHs):** PAHs are organic pollutants formed during the incomplete combustion of plastics and other organic materials in e-waste. PAHs are carcinogenic and can contaminate soil, water, and air.

Status of E-Waste

Global

- According to the Global E-waste Monitor 2022 by the International Telecommunication Union (ITU), the world generated 57.4 million metric tons (Mt) of e-waste in 2022.
- Asia is the largest contributor to e-waste, generating 24.9 Mt in 2022, followed by Europe with 12.9 Mt and North America with 11.7 Mt.

India

- According to the "E-waste Management market in India 2022-2027" report India stands as the **third-largest** contributor to global e-waste production, trailing only China and the US.
- According to the **Central Pollution Control Board,** India generated **1.71 million metric tons** of e-waste in 2023.
- **More than 95%** of this waste is illegally recycled by the **informal** sector, which only adds to the problem.
- Notably, 65 cities across India are responsible for over 60% of the nation's e-waste output, while 10 states account for 70% of the total e-waste generated.

Causes of E-Waste Accumulation

- **Rapid tech advancements:** Constant introduction of new electronic gadgets accelerates disposal of older devices, contributing to massive e-waste volumes.
- **Limited awareness:** Lack of understanding about the hazards of improper e-waste disposal leads to careless discarding of electronics with regular trash.
- **Inadequate recycling infrastructure:** Many nations lack proper systems for collecting and recycling e-waste, resulting in illegal dumping or unsafe disposal methods.
- **Weak regulations:** Insufficient laws and enforcement mechanisms allow manufacturers and consumers to avoid responsible e-waste management, exacerbating the issue.
- **Reducing cost and Integration of IT in every domain of life:** Adoption and integration of IT hardware in small everyday devices coupled with falling cost is leading to exponential increase in this category. Ex EV cars and solar panels will start reaching end of the lifecycle of the product coming years, will become leading source of e-waste.

Consequences of E-Waste Accumulation

- **Environmental Impact:** E-waste accumulation leads to environmental pollution and degradation. Leaching of toxic substances from e-waste contaminates groundwater, affects soil fertility, and contributes to air pollution, exacerbating environmental challenges.
- **Health Risks:** E-waste accumulation poses serious health risks to individuals involved in informal recycling activities and nearby communities. Exposure to toxic fumes, dust, and pollutants during e-waste processing can lead to respiratory illnesses, neurological disorders, and reproductive problems.
- **Resource Depletion:** E-waste accumulation results in the loss of valuable resources and materials, contributing to resource depletion and unsustainable consumption patterns. Inefficient management practices lead to underutilization of resources and increased demand for virgin materials.
- **Social Implications:** E-waste accumulation disproportionately affects vulnerable communities and marginalized populations. Informal recycling activities in low-income neighborhoods expose workers and residents to health hazards and economic exploitation, perpetuating cycles of poverty.
- **Economic Losses:** Inadequate e-waste management results in missed opportunities for job creation, innovation, and sustainable development. Proper recycling and recovery of materials are essential to conserve resources and promote sustainable resource management practices.

IGNITE YOUR MIND

E-Waste Explosion

Imagine our homes overflowing with discarded electronic devices, containing harmful materials that pose environmental and health risks. What are the challenges associated with managing electronic waste (e-waste), and how can we promote responsible disposal practices?

E-WASTE MANAGEMENT

E-Waste Management Cycle

E-waste management involves the proper handling, recycling, and disposal of electronic devices to minimize their environmental impact and ensure the responsible use of resources.

Key Stages in E-Waste Management Cycle

- **Collection:** During the collection phase of e-waste management, discarded electronic devices are gathered from various sources such as households, businesses, and institutions. Material recovery starts at this stage as devices are collected for the purpose of extracting valuable materials for recycling.

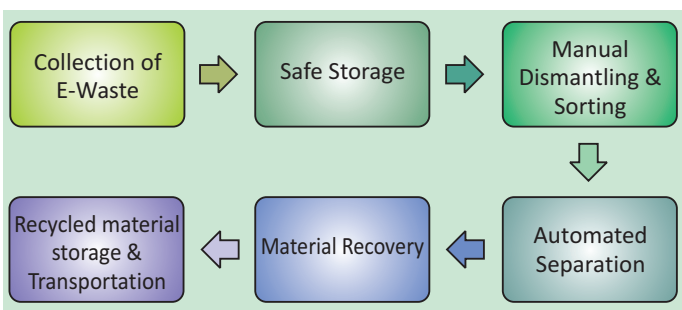


Fig. 10.22: E-Waste Management Cycle

- **Sorting and Segregation:** Once collected, e-waste undergoes sorting and segregation to separate recyclable materials from non-recyclable components. Material recovery efforts focus on identifying and extracting valuable resources such as metals (e.g., copper, gold, silver), plastics, glass, and other materials that can be reused or recycled.
- **Processing and Recycling:** After sorting, e-waste is processed to recover valuable materials through recycling. Material recovery techniques involve dismantling electronic devices and shredding them into smaller pieces. These pieces are then processed to separate different materials using methods such as mechanical shredding, magnetic separation, and chemical processes.

- **Refurbishment and Reuse:** Material recovery also includes refurbishing and reusing components and devices that are still functional or can be repaired. Recovered materials from e-waste can be used to refurbish electronic devices, extending their lifespan and reducing the demand for new resources.
- **Disposal of Hazardous Materials:** In addition to recovering valuable materials, material recovery also involves the safe disposal of hazardous components found in e-waste. Hazardous materials such as batteries, circuit boards, and mercury-containing components are carefully removed and disposed of using specialized methods to prevent environmental contamination.

Challenges in E-Waste Management

- **Informal Recycling:** Much of the world's e-waste is recycled informally in developing countries, often under unsafe and unregulated conditions, leading to environmental pollution and health hazards for workers.
  - As per the **ICEA report,** the management of e-waste in India is largely informal, with around **90% of e-waste collection and 70% of recycling** handled by the informal sector.
- **Resource Recovery:** Recovering valuable materials from e-waste, such as metals and rare earth elements, requires specialized techniques and technologies that are not widely available.
- **Data Security:** E-waste disposal must address data security concerns to prevent the unauthorized access or misuse of personal or sensitive information stored on electronic devices.
- **Legislation and Enforcement:** Inadequate legislation, weak enforcement mechanisms, and lack of awareness contribute to poor e-waste management practices and illegal dumping of e-waste in many regions.

Global Initiatives taken to Deal with E-Waste

- **StEP Initiative (Solving the E-waste Problem):** Multistakeholder initiative focusing on sustainable e-waste management. Promotes lifecycle assessment, eco-design, and responsible recycling practices.
- **Global E-waste Statistics Partnership (GESP):** Collaboration between the UN University and the International Telecommunication Union. Improves data collection, monitoring, and reporting on global e-waste generation and management.
- **Basel Convention on the Control of Transboundary Movements of Hazardous** Wastes and their Disposal: International treaty regulating the movement and disposal of hazardous waste, including e-waste.
- **R2 Code of Practices** stands as a guiding framework within the realm of electronics recycling and refurbishment, emphasizing responsible and sustainable practices. Here R2 stands for "Responsible Recycling." Developed by **SERI (Sustainable Electronics Recycling International)**, it outlines principles for the safe and ethical management of electronic waste. The code addresses various aspects including environmental protection, worker health and safety, data security, and downstream due diligence. By adhering to the R2 Code of Practices, organizations demonstrate their commitment to mitigating the environmental impact of e-waste while upholding transparency and accountability throughout the recycling process.
- **Right to Repair:** Many European countries have given legal backing to right to repair especially for electronics products, which will help in reducing discard rate of products.

National Initiatives for EWM in India

1. E-Waste Management Rules, 2016

- The E-Waste Management Rules, 2016, introduced by the Government of India, mandate extended producer responsibility (EPR) for manufacturers, importers, and producers of electronic products.
- Under these rules, producers are required to collect a certain percentage of e-waste generated from their products and ensure its environmentally sound recycling or disposal.
- Companies like **Apple, Dell, and Lenovo** have established take-back programs and tie-ups with authorized recyclers to comply with these regulations.

2. E-Waste (Management) Rules 2022

The Ministry of Environment Forest and Climate Change has notified **E-Waste (Management) Rules, 2022** on 2nd November, 2022. These rules will **replace E-waste (Management) Rules, 2016** and will be effective from 1st April, 2023. **Key Provisions include:**

- **Extended Producer Responsibility (EPR):** Producers of electrical and electronic equipment (EEE) are mandated to implement EPR framework. Producers are responsible for collecting a percentage of e-waste generated from their products and ensuring environmentally sound management.
- **Registration:** All the manufacturers, producers, refurbishers and recyclers are required to register on a portal developed by the **Central Pollution Control Board(CPCB).**
- **Collection Targets:** Producers are required to achieve specific collection targets for e-waste, which are set based on the quantity of EEE placed on the market.
- **Authorized Collection Centres:** The rules require producers to set up authorized collection centres and take-back mechanisms for the collection of e-waste from consumers.

- **Reduction of hazardous substances:** Under the E-Waste Management Rules, provision for reduction of hazardous substances in manufacturing of Electrical and Electronic Equipment (EEE) has been provided.

3. **Establishment of E-Waste Collection Centres**
   - Several states and municipalities in India have set up e-waste collection Centres to facilitate the proper disposal of electronic waste.
   - **Example: The Municipal Corporation of Greater Mumbai (MCGM)** has established e-waste collection Centres at various locations across the city, allowing residents to drop off their old electronic devices for recycling.
4. **Capacity Building and Training**
   - Organizations and institutions in India are actively involved in capacity-building initiatives to enhance skills and knowledge in e-waste management.
   - **Example: The Electronics Sector Skills Council of India (ESSCI)** offers training programs and certification courses for professionals working in the electronics and recycling sectors.

Way Forward

- **Extended Producer Responsibility (EPR):** Implementing EPR schemes to hold manufacturers responsible for the collection, recycling, and disposal of their products at the end of their life cycle.
- **Formal Recycling Infrastructure:** Developing formal e-waste recycling facilities with proper equipment and safety measures to ensure environmentally sound recycling and disposal practices.
- **Circular Economy Approaches:** Promoting circular economy models that emphasize product reuse, repair, remanufacturing, and recycling to minimize e-waste generation and resource consumption.
- **Consumer Awareness and Education:** Educating consumers about the importance of responsible e-waste disposal, proper recycling methods, and the environmental and social impacts of e-waste.

BIO-MEDICAL WASTE

Bio-medical waste refers to any waste generated during diagnosis, treatment, or immunization of human beings or animals, or in research activities pertaining to medical sciences.

Types of Bio-Medical Waste

General Waste

- **Sharps:** Needles, syringes, scalpels, broken glass, and other sharp objects that can cause injury or transmit infections.
- **Pathological Waste:** Tissues, organs, body parts, and fluids removed during surgery or autopsy.
- **Pharmaceutical Waste:** Expired, unused, or contaminated medications, drugs, and vaccines.

Category	Waste description	Name of Wastes
Category No. 1	Human anatomical waste	Blood and blood products, Placenta, Removed tumors and other surgically removed body parts, Excreta
Category No. 2	Animal Wastes	Not found
Category No. 3	Microbiology and biotechnical wastes	Culture media and plates, vaccine wastes. Reagents used in microbiological laboratory studies.
Category No. 4	Waste Sharps	Needles, syringes, scalpels, glass bits, broken ampoules
Category No. 5	Discarded medicine and cytotoxic drugs	Discarded medicines, packaging material, cartons.
Category No. 6	Soiled wastes	Soiled cotton dressings, plaster casts, soiled beddings, linen, gloves, masks
Category No. 7	Solid wastes	IV Infusion sets and tubings, catheters.
Category No. 8	Liquid Waste	Bleaching powder solution, household phenyl solution
Category No. 9	Incineration Ash	Incineration ash
Category No. 10	Chemicals used in production of biomedical products and for the disinfection	Bleaching powder, DDT

Infectious Waste

- Waste contaminated with blood, bodily fluids, or other potentially infectious materials.

Non-Infectious Waste

- **Chemical Waste:** Laboratory reagents, disinfectants, and other chemicals used in medical procedures.
- **Radioactive Waste:** Materials contaminated with radioactive substances, such as diagnostic and therapeutic isotopes.

Status of Biomedical Waste

Global Level

- According to the World Health Organization (WHO), nearly **85%** of waste generated by hospitals is **general waste** and about **15%** of waste is **biomedical waste**, composed of **10% infectious wastes** and **5% non-infectious wastes** like **radioactive** and **chemical wastes.**

India

- **CPCB Report:** India generated around **101 Metric Tonnes per day (MT/day)** of COVID-19-related bio-medical waste during the covid pandemic in addition to the regular bio-medical waste generation of about **609 MT per day.**
- **Waste generation from the hospitals:** The quantum of waste that is generated in India is estimated to be **1-2 kg per bed per day** in a hospital and 600 gm per day per bed in a general practitioner's clinic.
- Total bio-medical waste generation capacity in the country: **484 Tonnes Per Day (TPD)**

Causes of Biomedical Waste Accumulation

- **Inadequate segregation:** Failure to separate hazardous biomedical waste from non-hazardous material contaminates the entire waste stream, making it unsafe for disposal.
- **Limited infrastructure and technology:** Many areas lack proper facilities such as incinerators and autoclaves designed for effective and safe biomedical waste management.
- **Improper disposal:** Open dumping, burning, and mixing biomedical waste with general waste pose significant health and environmental risks due to exposure to pathogens and toxins.
- **Lack of awareness and training:** Healthcare workers and the public often lack awareness of the risks associated with improper biomedical waste disposal, leading to careless practices.
- **Weak regulations and enforcement:** Insufficient regulations and enforcement allow healthcare facilities and individuals to dispose of waste improperly without facing consequences, exacerbating the problem.
- **Expanding medical sector:** Increasing population, rising incomes and advancing biotech sector has resulted in expansion of medical labs, personalised medicines, preventive care along with meeting the previously unmet medical demands of the country resulting in the expansion of the bio medical waste.

Consequences of Biomedical Waste Accumulation

Improper management of bio-medical waste poses significant health risks to healthcare workers, patients, waste handlers, and the general public. Exposure to bio-medical waste can lead to:

- **Transmission of Infections:** According to the World Health Organization (WHO), healthcare workers in many countries face occupational hazards from exposure to biomedical waste, leading to an increased risk of infections such as **HIV, hepatitis B, and hepatitis C.**
- **Accidental Injuries:** Sharps injuries can result in puncture wounds, cuts, and exposure to bloodborne pathogens.
- **Antibiotic Resistance:** Improper disposal of pharmaceutical waste can contribute to the development of antibiotic-resistant bacteria and other pathogens posing challenges for disease treatment.
- **Environmental Pollution:** Biomedical waste contains a variety of hazardous substances, including infectious agents, pharmaceuticals, and heavy metals, which can contaminate soil, water, and air if not properly managed.
- **Regulatory Compliance:** Compliance with stringent regulations and guidelines for biomedical waste management can be challenging for healthcare facilities, waste management facilities, and regulatory authorities.
- **Emerging Issues:** Rapid advances in medical technology, pharmaceuticals, and healthcare practices may introduce new types of biomedical waste with unique characteristics and management challenges.

BIO-MEDICAL WASTE MANAGEMENT

Biomedical waste management involves the safe handling, collection, treatment, and disposal of waste generated from healthcare facilities, laboratories, research institutions, and other biomedical facilities.

This waste includes potentially infectious materials, sharps, pathological waste, pharmaceuticals, and other hazardous substances. Effective biomedical waste management is essential to protect public health, prevent the spread of infections, and minimize environmental pollution.

Biomedical Waste Management Cycle

Fig. 10.23: Biomedical Waste Management

Key stages of Biomedical waste management cycle

- **Segregation:** Segregating bio-medical waste at the point of generation into different categories based on its type, such as infectious waste, sharps, and pharmaceutical waste.
- **Collection:** Using leak-proof containers, color-coded bins, and puncture-resistant containers for safe collection and storage of bio-medical waste.
- **Transportation:** Transporting bio-medical waste in dedicated vehicles equipped with appropriate safety measures to prevent spills, leaks, and exposure during transit.
- **Treatment and Disposal:** Treating bio-medical waste through methods such as autoclaving, incineration, microwaving, or chemical disinfection to inactivate pathogens and reduce its volume before final disposal.
- **Monitoring and Compliance:** Implementing monitoring mechanisms, regular inspections, and quality control measures to ensure compliance with bio-medical waste management regulations and standards.

Challenges in Biomedical Waste Management

- **Health Risks:** Improper handling and disposal of biomedical waste pose significant health risks to healthcare workers, waste handlers, patients, and the general public. Exposure to infectious agents and hazardous chemicals can lead to infections, injuries, and long-term health effects.
- **Regulatory Compliance:** Compliance with stringent regulations and guidelines for biomedical waste management can be challenging for healthcare facilities. Lack of awareness, inadequate infrastructure, and limited resources may hinder compliance with waste segregation, storage, transportation, and disposal requirements.
- **Inadequate Infrastructure:** Many healthcare facilities, especially in resource-limited settings, lack proper infrastructure and facilities for biomedical waste management. This includes insufficient storage space, inadequate waste segregation systems, and limited access to safe disposal methods such as incineration or autoclaving.
- **Training and Awareness:** Proper training and awareness among healthcare workers and waste handlers are essential for safe and effective biomedical waste management. However, inadequate training programs and limited awareness about the risks associated with biomedical waste may lead to improper handling and disposal practices.
- **Cost Constraints:** Effective biomedical waste management often requires investment in specialized equipment, infrastructure, and personnel. Healthcare facilities, particularly in low-resource settings, may face financial constraints that limit their ability to implement proper waste management practices.

Global Initiatives in Biomedical Waste Management

Basel Convention

- The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal is a global treaty aimed at regulating the transboundary movement of hazardous wastes and ensuring their environmentally sound management.
- India has implemented the provisions of the convention by enacting national legislation, such as the **Hazardous Waste Management Rules 2016**, which regulate the generation, handling, transport, and disposal of hazardous wastes within the country.

Global Alliance for Waste Management

- **Multi-stakeholder partnership:** This alliance brings together governments, businesses, NGOs, and other stakeholders to collaborate on improving waste management practices globally.
- **Focuses on sustainable solutions:** The alliance promotes the adoption of innovative technologies and approaches for waste management, including those specifically tailored for biomedical waste.

IGNITE YOUR MIND

Beyond Borders: Waste management challenges transcend national boundaries. How do international conventions and treaties, like the Basel Convention, encourage global cooperation in addressing this issue?

National Initiatives

Biomedical Waste Management Rules, 2016

- The **Biomedical Waste Management Rules, 2016**, are regulations established by the Government of India to ensure the proper **handling, treatment, and disposal of biomedical waste** generated in healthcare facilities.
- These rules **replace the Biomedical Waste (Management and Handling) Rules, 1998**, and aim to streamline biomedical waste management practices, minimize environmental pollution, and protect public health.
- **Key features**
  - **Segregation and Classification:** The rules specify **guidelines** for the segregation of biomedical waste at the point of generation into different categories, such as **sharps, infectious waste, pathological waste, chemical waste, and general biomedical waste.**
    - Each category has designated **color-coded bins** or containers for segregation.

- **Storage and Transportation:** Biomedical waste must be stored in **leak-proof, puncture-resistant containers** that are properly labeled with the biohazard symbol and waste category. Healthcare facilities are required to maintain separate storage areas for different types of biomedical waste.
- **Treatment and Disposal:** Biomedical waste must undergo treatment to render it non-infectious and safe for disposal. Treatment methods include **autoclaving**, **incineration, microwave treatment, chemical disinfection, and other approved technologies**. Disposal of treated biomedical waste must be carried out in accordance with prescribed procedures to prevent environmental contamination and public health risks.

Guidelines for Treatment and Disposal of Waste Generated During Healthcare Activities During COVID-19 Pandemic

- These guidelines aimed to address the increased generation of infectious waste, including personal protective equipment (PPE), contaminated materials, and biomedical waste, due to the healthcare response to the pandemic.

Way Forward

- **Enhanced Regulatory Enforcement:** Strengthening enforcement of existing regulations and guidelines for biomedical waste management can help ensure compliance and accountability among healthcare facilities. Regular inspections, monitoring, and penalties for non-compliance can incentivize adherence to waste management standards.
- **Investment in Infrastructure and Technology:** Governments and healthcare institutions should invest in infrastructure, equipment, and technology for safe and efficient biomedical waste management. This includes establishing centralized waste treatment facilities, implementing waste segregation systems, and adopting safer disposal methods such as non-incineration technologies.
- **Training and Capacity Building:** Comprehensive training programs should be provided to healthcare workers, waste handlers, and other stakeholders involved in biomedical waste management. Training should cover waste segregation, handling, transportation, and disposal protocols, as well as infection control measures and occupational safety practices.
- **Public Awareness and Education:** Public awareness campaigns and educational initiatives are essential for promoting understanding of the risks associated with biomedical waste and encouraging responsible waste management practices. Engaging communities, patients, and healthcare professionals in discussions about waste management can help dispel myths and reduce stigma.
- **Research and Innovation:** Continued research and innovation in biomedical waste management technologies and practices are needed to develop cost-effective, environmentally sustainable solutions. This includes exploring alternatives to incineration, improving waste treatment processes, and implementing advanced waste tracking and monitoring systems.
- **Collaboration and Partnerships:** Collaboration among government agencies, healthcare institutions, waste management companies, and civil society organizations is crucial for addressing the complex challenges of biomedical waste management. Multi-stakeholder partnerships can facilitate knowledge sharing, resource mobilization, and coordinated efforts to improve waste management systems.

OTHER TYPES OF WASTE

Type of Waste	Causes	Impacts	Mitigation Measures
Agricultural Waste	Crop production	Soil degradation Water pollution Greenhouse gas emissions Habitat destruction Biodiversity loss Health risks	Composting Precision agriculture Sustainable farming practices Education and awareness
Organic Waste	Household activities Food processing	Methane emissions Odours and pests Soil and water contamination	Composting Anaerobic digestion Source reduction Separate collection and recycling Public awareness

Radioactive Waste	Nuclear power plants Medical facilities	Cancer risk Genetic mutations Environmental contamination Health hazards	Strict regulations Engineered containment Monitoring and surveillance Research and development
Construction and Demolition Waste	Building construction Renovation Demolition	Visual pollution Habitat destruction Land degradation Air pollution Increased landfill pressure	Design for deconstruction Waste segregation Recycling Centralized recycling facilities Enforcement of regulations

CIRCULAR ECONOMY

Fig. 10.24: Circular Economy

- The circular economy is an **economic model** that aims to **minimize waste and resource depletion** by keeping products, materials, and resources in use for as long as possible through strategies such as recycling, reuse, and remanufacturing.
- In a circular economy, the traditional **"take-make-dispose" linear model** is replaced with a **closed-loop system** where resources are regenerated and continuously circulated within the economy.
- This approach promotes **sustainable production and consumption practices, reduces environmental impacts, and fosters economic resilience and innovation.**

Principles of Circular Economy

The principles of a circular economy emphasize **sustainable resource management and waste reduction** by promoting the following strategies:

- **Reduce:** The principle of reduction involves minimizing the consumption of resources and the generation of waste at the source. This includes designing products and processes to be more resource-efficient, optimizing material use, and reducing unnecessary packaging or components.
  - **Example:** Designing products with **minimal packaging,** such as eliminating unnecessary plastic wrap on fruits and vegetables, reduces the amount of waste generated at the consumer level.
- **Reuse:** Reuse involves extending the lifespan of products, components, or materials by using them multiple times for the same or different purposes. This can involve refurbishing or repairing products to restore their functionality or repurposing materials for alternative applications.
  - **Example:** The concept of **"upcycling"** has gained popularity, where discarded materials or products are transformed into new items of higher value. For instance, **discarded shipping containers** are **repurposed** into **modular homes or office spaces**, reducing the need for new construction materials.
- **Recycle:** Recycling entails recovering materials from products or waste streams and converting them into new products or raw materials. This helps to close the loop in the production cycle, reduce the extraction of virgin resources, and minimize waste sent to landfills or incineration.
  - **Example: Recycling paper waste** to produce new paper products conserves trees and reduces deforestation.
- **Repair:** Repair involves fixing products or components that are damaged or malfunctioning instead of discarding them. Repairing items extends their useful life, reduces the need for replacement, and conserves resources by avoiding the production of new goods.
  - **Example:** Repairing electronic devices such as smartphones and laptops extends their lifespan and reduces electronic waste. Repair shops and DIY repair tutorials help users fix issues such as broken screens or malfunctioning components.
- **Refurbish:** Refurbishing involves restoring or renovating products to a like-new condition, often through cleaning, maintenance, or upgrading. Refurbished items can be resold or reintroduced into the market, providing cost-effective alternatives to new products while reducing waste.
  - **Example:** Refurbishing used appliances such as refrigerators or washing machines restores their functionality and appearance, making them suitable for resale at a lower cost than new appliances.

- **Remanufacture:** Remanufacturing involves disassembling products, refurbishing individual components, and reassembling them to create products that are equivalent or superior in performance to new ones. This process maintains the value and functionality of existing materials and reduces the environmental impact of manufacturing.
  - **Example:** Remanufactured engines are widely used in the automotive industry, offering a sustainable alternative to new engines. Companies like **Caterpillar** and **Cummins** remanufacture engines by **disassembling, cleaning, and replacing worn parts,** reducing material consumption and energy use.

IGNITE YOUR MIND

Design for Sustainability: Imagine products designed with their entire lifecycle in mind, minimizing waste and promoting easy disassembly and recycling. How can we encourage sustainable product design and consumption patterns?

Circular Economy in India

- The circular economy is an economic model aimed at reducing waste and maximizing resource efficiency by promoting the reuse, recycling, and regeneration of materials and products.
- In India, initiatives to transition towards a circular economy include waste management programs, recycling initiatives, and sustainable production and consumption practices.
- The government and various stakeholders are working to promote circularity in sectors such as manufacturing, construction, textiles, and electronics through policy interventions, incentives, and awareness campaigns.

Need for Circular Economy in India

- **Resource Scarcity:** With a population of more than **1.4 billion** people, India accounts for **18%** of the global population, living on only **2.4 %** of the world's surface. Consequently, India faces **resource scarcity** due to its rapidly growing population and industrialization.
  - Embracing circular economy principles can help conserve finite resources by promoting recycling, reuse, and resource efficiency.
- **Environmental Degradation:** Traditional linear economic models, characterized by **"take-make-dispose"** patterns, contribute to **environmental degradation** through resource depletion, pollution, and waste generation.
  - Transitioning to a circular economy can mitigate these environmental impacts by minimizing resource extraction and waste generation.
- **Waste Management Crisis:** According to the **State of India's Environment 2023 report**, Municipal Solid Waste (MSW) generation in India is estimated to be around **150,000 tonnes per day (TPD).** This is expected to increase to **165 million tonnes by 2030 (CPCB).**
  - India's recycling rate currently stands at **only 18 percent,** which is well below the **global average of 35 percent.**
    - Adopting circular economy approaches, such as waste minimization, recycling, and product stewardship, can alleviate the burden on landfills and reduce environmental pollution.
- **Economic Growth and Competitiveness:** Embracing principles of the circular economy can drive economic growth and enhance competitiveness.
  - By promoting innovation, resource efficiency, and value retention throughout the product lifecycle, businesses can unlock new revenue streams, reduce production costs, and enhance their market position.
- **Climate Change Mitigation:** Circular economy strategies contribute to climate change mitigation by reducing greenhouse gas emissions associated with resource extraction, manufacturing, and waste management.
  - By promoting energy efficiency, renewable energy adoption, and carbon sequestration, circular economy practices can help India achieve its climate goals.
- **Social Equity and Inclusive Development:** Circular economy initiatives can create opportunities for social inclusion and sustainable development.
  - By fostering entrepreneurship, job creation, and community empowerment, the circular economy can contribute to poverty alleviation and enhance the well-being of marginalized communities.

Measures to Promote Circular Economy in India

- **Circular Economy Cell: Circular Economy Cell (CE Cell)** was constituted in **NITI Aayog** in September, 2022 as a dedicated unit to work in the area of Circular Economy.
  - 10 sectoral Circular Economy action plans were finalized in NITI Aayog for implementation by stakeholder Ministries/Departments.
- **G-20 outcomes:** During its G-20 presidency, India has prioritized **four key areas** for advancing the circular economy:
  - Enhancing **circularity in the steel sector**
  - Promoting **Extended Producer Responsibility (EPR)**
  - Fostering a **circular bioeconomy**
  - Establishing an **industry-led coalition** to drive resource efficiency and circular economy initiatives.
- **Policy measures:** Guidelines outlined in policies like **Plastic Waste Management Rules, e-Waste Management Rules, Construction and Demolition Waste Management Rules and Metals Recycling Policy** are aligned to **circular economy** principles.

- **LiFE Movement:** Aimed at inducing behaviour change in people, inducing them to adopt environment conscious lifestyle which includes responsible consumption (SDG Goal 12). It will help in reducing waste by adopting reuse, recyling etc and create market for sustainable products which will give price signals to corporations to produce such products, which in turn directs investments towards sustainability. It aims to harvest the power of consumer in free market economy to usher sustainable production in free market economy where demand is the ultimate driver of investments.
- **Industrial recycling:** NITI Aayog promoted the usage of fly ash and slag produced in the steel industry in other sectors like road construction, agriculture, cement, etc.
- **Eleven focus areas:** To expedite the transition of the country from a linear to a circular economy, 11 focus areas have been identified. The focus areas include 11 end-of-life products/recyclable materials/wastes that either continue to pose considerable challenges or are emerging as new challenge areas that must be addressed in a holistic manner.

S. No.	Focus Area	Concerned Line Ministry/Institute
1	Municipal Solid Waste and Liquid Waste	Ministry of Housing and Urban Affairs
2	Scrap Metal (Ferrous and Non-Ferrous)	Ministry of Steel
3	Electronic Waste	Ministry of Electronics and Information Technology
4	Lithium Ion (Li-ion) Batteries	NITI Aayog
5	Solar Panels	MNRE
6	Gypsum	Department for Promotion of Industry and Internal Trade
7	Toxic and Hazardous Industrial Waste	Department of Chemicals and Petrochemicals
8	Used Oil Waste	Ministry of Petroleum and Natural Gas
9	Agriculture Waste	Ministry of Agriculture and Farmers' Welfare
10	Tyre and Rubber Recycling	Department for Promotion of Industry and Internal Trade
11	End-of-life Vehicles (ELVs)	Ministry of Road Transport and Highways

Challenges to Circular Economy in India

While India has embraced the circular economy (CE) concept, several challenges hinder its full potential:

- **Lack of awareness and understanding:** CE is still a relatively new concept in India, requiring broader awareness among businesses, consumers, and policymakers.
- **Insufficient policy and regulations:** Supportive policies exist, but a more robust framework with clear incentives and regulations is needed to drive widespread CE adoption.
- **Limited access to finance and investment:** Attracting investment for CE projects and infrastructure development requires innovative financing solutions and risk-sharing mechanisms.
- **Gaps in infrastructure and technology:** Upgrading waste collection, sorting, and processing infrastructure is crucial, alongside investment in technologies for resource recovery and reuse.
- **Consumer behavior change:** Shifting mindsets towards repair, reuse, and responsible consumption requires sustained awareness campaigns and incentives.
- **Informal waste sector:** Integrating the informal sector into the formal waste management system is crucial for effective resource recovery and CE implementation.
- **Skill development:** Building a skilled workforce equipped for CE jobs in areas like repair, refurbishment, and resource management is vital.

Way Forward

- **Prioritization and Actionable Steps:** Identify key sectors and develop targeted strategies like green building codes, take-back schemes for electronics, and extended producer responsibility for textiles.
  - **Example:** The India Construction Materials Environmental Resource Centre (ICEMERC) promotes resource efficiency in construction, offering guidelines and tools for recycled content and circular design.
- **Localized Strategies:** Implement pilot projects in diverse regions like urban slums and rural areas, adapting solutions to local contexts.
  - **Example: The SELCO Foundation's "Waste to Wealth" program** in rural India uses locally available waste materials like **bioplastics** and **upcycled textiles** to create livelihood opportunities.
- **Leveraging Existing Initiatives:** Integrate circular economy principles into existing government programs.
  - **Example:** Align and integrate the **Swachh Bharat Mission (Clean India Mission) for waste collection and the Skill India Mission for workforce development.**

- **Bolster Innovation and Technology:** Support Local Innovators and invest in startups which develop innovative solutions for recycling, resource recovery, and circular design.
  - **Example: E-Parisaraa Pvt. Ltd** is **India's first Government authorized electronic waste recycler** engaged in the handling, recycling and reusing of Waste Electrical and Electronic Equipment (WEEE) in eco friendly way.
- **Performance Measurement and Monitoring:** Establish clear metrics like resource efficiency, waste reduction, and job creation in the circular economy to track progress.
  - **Example:** The **NITI Aayog's "Circular Economy Framework"** outlines key indicators for measuring progress towards circularity in various sectors.
- **International Collaboration:** Foster partnerships and collaboration between government, industry, academia, and civil society to drive circular economy initiatives and address challenges collectively.
  - **Example:** Recently, India joined the **Global Alliance for Circular Economy and Resource Efficiency (GACERE)** to enhance coordination with countries for developing a robust circular economy ecosystem.
    - **GACERE** is an alliance of governments at the global level willing to work together on and advocate for a global just circular economy transition and more sustainable management of natural resources.
    - **Established by:** The **European Commission** on behalf of the **European Union (EU)**, and by **UNEP**, in coordination with the **UNIDO**.

"Waste to Wealth"

The **"Waste to Wealth" (WtW)** concept promotes viewing waste not as a burden, but as a valuable resource. It aims to transform waste materials into valuable products or resources, minimizing waste disposal and creating economic and environmental benefits.

Approaches in WtW

- **Recycling:** Converting used materials into new products (e.g., plastic bottles into clothing).
  - **Example: 'Oceanness'** is a purpose driven apparel brand which makes eco-friendly clothes, made from **100% recycled plastic bottles**, without being mixed with other materials.
- **Composting:** Transforming organic waste into nutrient-rich fertilizer.
  - **Example:** The decentralized composting system in **Pune**, where households compost organic waste helps in reducing landfill burden, creating nutrient-rich fertilizers and is aligned to its goal of becoming a **'zero landfill city'.**
- **Waste-to-Energy (WtE):** Generating electricity or heat from waste through combustion or other processes.
  - **Example: Indore** has a WtE plant that processes municipal solid waste to generate electricity, reducing reliance on fossil fuels and managing waste effectively.
- **Upcycling:** Reusing discarded materials for new purposes with added value.
  - **Example:** The **Hasiru Dala Foundation** in **Bengaluru** upcycles discarded materials like wood and plastic into unique and functional furniture, promoting sustainability and creating jobs.
- **Biogas production:** Anaerobic digestion of organic waste to produce methane for energy.
  - **Example:** As envisioned in the Union Budget 2023-24, **500 new 'waste to wealth' plants** under the **GOBARdhan scheme** will be established for promoting **circular economy.**
    - These will include **200 compressed biogas (CBG) plants, including 75 plants in urban areas, and 300 community or cluster-based plants.**

Benefits	Challenges
Reduces reliance on virgin resources: Conserves natural resources like trees and metals. **Minimizes waste disposal:** Reduces reliance on landfills and incineration. **Creates new economic opportunities:** Generates jobs in waste collection, processing, and product development. **Lowers environmental impact:** Reduces greenhouse gas emissions and pollution.	**Investment and infrastructure:** Requires investment in new technologies and processing facilities. **Market development:** May require developing markets for recycled products or WtE energy. **Public awareness and behavior change:** Requires promoting waste reduction and proper waste segregation.

Overall, the **Waste to Wealth** concept represents a shift towards more **sustainable and resource-efficient waste management practices,** emphasizing the potential for turning waste into valuable resources, fostering innovation, and contributing to the transition towards a **circular economy.**

With only **2%** of the world's landmass and 4% of freshwater resources, a linear economy model of **'Take-Make-Dispose'** would constrain India's manufacturing sector and, consequently, the overall economy.

Therefore, it is essential to recognize and revolutionize the material flow in the manufacturing process and shift towards a circular economy, which provides multipronged economic and ecological benefits.

Benefits of Circular Ecnomy

- **Resource Efficiency:** By keeping resources in use for longer periods through recycling, reuse, and remanufacturing, the circular economy minimizes resource extraction and reduces waste generation, leading to greater resource efficiency.
- **Environmental Protection:** A circular economy reduces pollution, greenhouse gas emissions, and habitat destruction associated with resource extraction, manufacturing, and waste disposal, thus helping to protect ecosystems and biodiversity.
- **Waste Reduction:** By designing products for longevity and facilitating recycling and reuse, the circular economy minimizes waste generation and landfilling, contributing to a more sustainable approach to waste management.
- **Cost Savings:** Adopting circular economy practices can lead to cost savings for businesses through improved resource efficiency, reduced material and energy costs, and lower waste management expenses.
- **Job Creation:** The transition to a circular economy creates new opportunities for employment in industries such as recycling, repair, refurbishment, and sustainable manufacturing, contributing to economic growth and social development.
- **Innovation and Entrepreneurship:** The circular economy fosters innovation and entrepreneurship by encouraging the development of new business models, technologies, and products that prioritize resource conservation and environmental sustainability.
- **Resilience to Supply Chain Disruptions:** By diversifying supply chains, reducing reliance on finite resources, and promoting local sourcing and production, the circular economy enhances resilience to supply chain disruptions and external shocks.

Challenges of a Circular Economy

- **Complexity and Coordination:** Implementing circular economy practices requires coordination across multiple stakeholders, including businesses, governments, consumers, and supply chain partners. Coordinating efforts and overcoming siloed approaches can be challenging.
- **Technological Barriers:** Developing and scaling up innovative technologies for recycling, remanufacturing, and resource recovery poses technical challenges and requires significant investment in research and development.
- **Financial Constraints:** Transitioning to a circular economy may require upfront investment in new infrastructure, technologies, and business models. Securing funding and overcoming financial barriers can be difficult, particularly for small and medium-sized enterprises (SMEs).
- **Behavioral Change:** Shifting consumer behaviors and preferences towards more sustainable consumption patterns, such as reuse and repair, can be challenging. Educating consumers and fostering awareness about the benefits of the circular economy is essential but requires time and resources.
- **Regulatory and Policy Frameworks:** Inconsistent or inadequate regulatory frameworks may hinder the adoption of circular economy practices. Clear and supportive policies, regulations, and incentives are needed to create an enabling environment for circularity.
- **Supply Chain Complexity:** Supply chains are often global and complex, making it challenging to trace and manage materials throughout their lifecycle. Building transparent and resilient supply chains that prioritize circularity requires collaboration and data sharing among stakeholders.
- **Cultural and Societal Norms:** Cultural norms and attitudes towards ownership, consumption, and waste disposal may not align with circular economy principles. Changing societal norms and fostering a culture of reuse and resource conservation requires social and behavioral change interventions.

Global Initiatives for the Circular Economy

- **Circular Economy Action Plan:** The European Union implements measures like eco-design requirements and extended producer responsibility to foster circularity.
- **Global Alliance for Circular Economy and Resource Efficiency (GACERE):** UN-supported initiative promoting collaboration and knowledge sharing on circular economy practices globally.
- **World Business Council for Sustainable Development (WBCSD):** Provides resources and guidance for businesses transitioning to circular models worldwide.

Way Forward

- **Investment in Innovation**: Encourage investment in the research and development of innovative technologies, materials, and processes that support circularity. Public-private partnerships and funding schemes can facilitate collaboration and accelerate the development and adoption of circular solutions.
- **Collaboration and Partnerships:** Foster collaboration among stakeholders, including businesses, governments, academia, and civil society, to share knowledge, resources, and best practices. Collaboration can help address common challenges, leverage collective expertise, and drive innovation in circular economy solutions.

- **Circular Design and Product Innovation:** Promote circular design principles and encourage product innovation that prioritizes durability, repairability, and recyclability. Design for disassembly and circular business models, such as product-as-a-service and sharing platforms, can help extend product life cycles and reduce waste generation.
- **Monitoring and Evaluation:** Establish monitoring mechanisms and performance indicators to track progress towards circular economy goals and measure the impact of circular initiatives. Regular evaluation and feedback loops can help identify gaps, address challenges, and refine strategies for continuous improvement.

IGNITE YOUR MIND

The Future We Choose: Imagine two scenarios for the future: one where waste management remains unsustainable, and another where we adopt innovative solutions and achieve a circular economy. What choices can we make today to shape a more sustainable future for waste management?

CONCLUSION

To achieve sustainable waste management, it is imperative to prioritize investments in waste infrastructure, enhance public awareness and participation, strengthen enforcement mechanisms, and foster collaboration between government agencies, the private sector, civil society, and communities. Additionally, there is a need for innovative approaches, technological solutions, and circular economy principles to maximize resource recovery, minimize waste generation, and promote a cleaner, healthier environment. Ultimately, effective waste management is not only essential for safeguarding public health and protecting the environment but also for fostering inclusive and sustainable development. By addressing waste management challenges comprehensively and collaboratively, India can pave the way towards a future where waste is managed responsibly, resources are conserved, and communities thrive in a cleaner and greener environment.

Climate Change and Global Warming

11

Climate encompasses long-term patterns and variations in temperature, humidity, wind, precipitation, and other atmospheric conditions within specific regions. It greatly influences ecosystems, wildlife, and human activities across diverse areas. Despite its apparent constancy, Earth has undergone significant climate changes over millions of years, including ice ages and warmer interglacial periods.

Global warming, a crucial aspect of climate change, denotes the rising trend in average air temperatures near the Earth's surface observed over the past one to two centuries. Primarily driven by human activities since the Industrial Revolution, this phenomenon has profound consequences, impacting landscapes, ecosystems, and societies globally.

Understanding these concepts sets the stage for exploring their complexities. This chapter delves into the multifaceted aspects of climate change and global warming, examining their impacts and advocating for sustainable practices to safeguard the planet and future generations.

Planet on Fire: A Simulation of Chaos

Step into a simulation where familiar landscapes – your city, your favorite beach – are ravaged by heatwaves, floods, and droughts. What unseen force is orchestrating this chaos? Can we prevent it from becoming our reality?

WHAT IS CLIMATE CHANGE?

Climate change denotes long term shifts in temperature and precipitation generally over 30 year period. It denotes an alteration in climate due to natural and anthropogenic reasons over comparable time periods. According to the United Nations Framework Convention on Climate Change (UNFCCC) in the contemporary times, it is attributed directly or indirectly to human activity, altering the global atmosphere's composition in addition to natural climate variability.

Quantified through observable impacts from an ongoing warming trend, climate change manifests as shifts in temperature, precipitation, snowfall, and wind patterns persisting over decades or more. While natural factors contribute, human activities since the 1800s have become the predominant force driving climate change.

WHAT IS GLOBAL WARMING?

The Intergovernmental Panel on Climate Change (IPCC) defines global warming as the observed increase in Earth's climate system's average temperature, affecting ocean temperatures, ice sheets, and sea levels. Primarily caused by human activities increasing greenhouse gas concentrations, it disrupts the natural balance, leading to melting glaciers, rising sea levels, and extreme weather events.

Fueled by unchecked greenhouse gas emissions, global warming poses a severe threat to life on Earth. Understanding its science and consequences is crucial for charting a course toward a sustainable future.

CLIMATE CHANGE vs. GLOBAL WARMING

While "global warming" and "climate change" are often used interchangeably, it's essential to recognize that "global warming" represents just one facet of the broader concept of climate change. A comparison of the two has been presented below.

Aspect	Climate Change	Global Warming
Definition	Refers to the alteration of climate patterns over extended periods, including temperature, precipitation, and wind patterns.	Refers specifically to the long-term increase in Earth's average surface temperature.
Causes	Caused by a combination of natural processes and human activities, such as deforestation and greenhouse gas emissions.	Primarily driven by human activities, particularly the release of greenhouse gases such as carbon dioxide and methane.
Impacts	Results in changes to weather patterns, sea levels, ecosystems, and biodiversity.	Contributes to rising sea levels, melting polar ice caps, and shifts in ecosystems and habitats.
Scope	Can manifest at both regional and global scales, affecting various aspects of the Earth's climate system.	Centers on the warming of the planet's surface temperatures as a result of increased greenhouse gas emissions.

Example	The melting of polar ice caps due to the increase in greenhouse gas emissions, leading to rising sea levels and loss of habitat for polar bears.	Changes in weather patterns resulting in more frequent and intense heat waves, storms, and droughts, impacting agriculture, water resources, and human health worldwide.

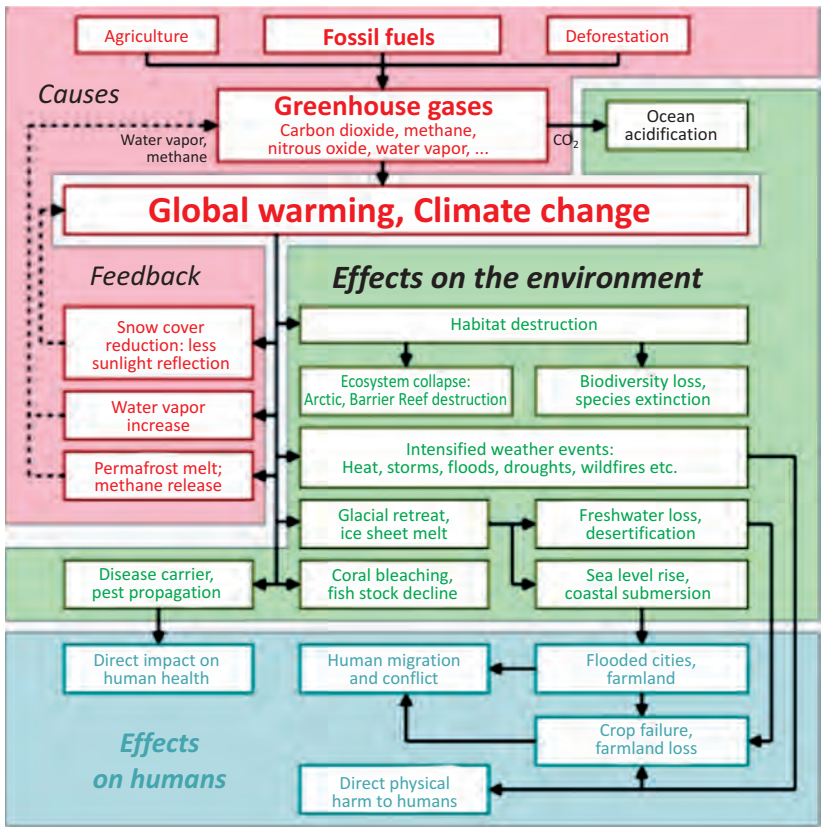


Fig. 11.1: Climate Change & Global Warming

While global warming is a specific aspect of climate change, climate change encompasses a broader range of climatic changes beyond just temperature increases. In recent times both phenomena are driven by human activities, particularly the release of greenhouse gases, and pose significant challenges that require urgent global action to mitigate their impacts.

UNDERSTANDING EARTH'S CLIMATE: A HISTORICAL PERSPECTIVE

Earth's Climate Cycles: A Journey Through Time

Earth has experienced eight cycles of ice ages and warmer periods over approximately 800,000 years. The most recent ice age ended about 11,700 years ago, ushering in the modern climate era and the rise of human civilization. These climate variations are primarily driven by subtle changes in Earth's orbit, affecting solar energy received by the planet.

Contemporary Climate Change: Human Influence Takes Center Stage

The current warming trend is distinct from natural cycles. Since the mid-1800s, human activities have been the primary driver of climate change, leading to an unprecedented rate of warming. Increased levels of atmospheric greenhouse gases, largely from human sources, trap more solar energy within the Earth system, resulting in widespread warming.

Impact on Earth's Systems: Widespread Changes Unfold

Rapid and extensive changes are observed in the atmosphere, oceans, cryosphere, and biosphere. Human activities have caused alterations to Earth's climate that surpass the norms of recent millennia.

Scientific Consensus: Unveiling Climate Realities

Earth-orbiting satellites and technological advancements provide scientists with comprehensive global datasets. Continuous monitoring reveals indicators and trends signaling a shifting climate. Scientists have recognized the impact of greenhouse gases, particularly carbon dioxide, in trapping heat since the mid-19th century. NASA's Remote sensing, weather stations, weather balloons, ships, buoys and other scientific instruments contribute to understanding how these gases affect infrared radiation transmission through the atmosphere.

Human-Induced Climate Change: Unequivocal Findings

Rigorous analysis confirms that increased greenhouse gas levels lead to warming of the Earth's surface. The scientific community agrees on the significant role of human activities in altering the planet's climate.

Understanding Climate Change Through Natural Records

- **Tree Rings:**
  - The width and color of **tree rings** serve as valuable indicators of past climate conditions.
  - Wider rings suggest periods of increased rainfall, while thinner rings signify drier years.
- **Rock Layers:**
  - Sedimentary rocks play a crucial role in recording changes in **temperature, rainfall,** and **ocean currents.**
  - By analyzing their composition and fossil content, scientists can uncover detailed information about historical **climate patterns.**
- **Pollen Records:**
  - Preserved **pollen grains** found in soils and lake sediments offer insights into past environments.
  - Changes in **plant species** and environmental conditions can be deduced from these records.
- **Ice Cores:**
  - Deep **ice cores** extracted from polar regions contain trapped air bubbles and layers of snow.
  - This unique archive provides a chronological record spanning thousands of years, aiding in the understanding of past climates.
- **Additional Sources:**
- Other natural records, including **coral reefs, cave speleothems,** and **lake sediments,** contribute valuable data to unravel past **climate change events.**

THEORIES OF CLIMATE CHANGE

Theories of climate change encompass various scientific explanations for the mechanisms and drivers behind shifts in Earth's climate over time. These theories draw from interdisciplinary research spanning atmospheric science, oceanography, geology, and related fields. Important theories include:

- **Greenhouse Gas Theory:** This theory suggests that changes in greenhouse gas concentrations, such as carbon dioxide (CO_2), methane (CH_4), and water vapor, in the atmosphere influence Earth's climate by trapping heat from the sun, resulting in a greenhouse effect that warms the planet's surface.
- **CO_2 theory:** T.C. Chamberlin proposed the carbon dioxide theory of climate change, which suggests that fluctuations in atmospheric carbon dioxide levels significantly contribute to global climate change.

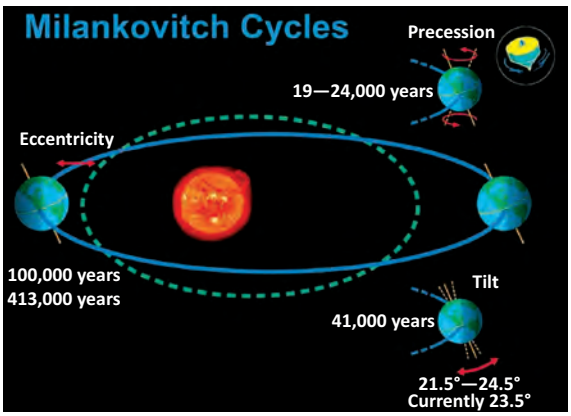


Fig. 11.2: Milankovitch Cycles

- **Milankovitch Cycles or Astronomical or Orbital Theory:** Proposed by Serbian scientist Milutin Milankovitch in the early 20th century, this theory proposes that variations in Earth's orbit, axial tilt, and precession (wobbling) contribute to cyclical changes in the distribution of solar radiation received by the Earth.
  - These orbital variations, occurring over tens of thousands to hundreds of thousands of years, are believed to drive the onset and duration of ice ages and interglacial periods.
- **Theories of Continental Drift:** Continental Drift theory proposed by Wegner, sea floor spreading by H.H. Hess, and plate tectonics by Morgan indicate that continents and ocean basins have been shifting for over 3.5 billion years.
  - These movements altered the positions of the equator and poles, impacting the horizontal distribution of continents and oceans. Geological evidence such as coal distribution suggests that continental drift may have influenced past climatic changes.
  - Changes in continental positions likely affected ocean currents and atmospheric circulation, altering temperature and precipitation distribution patterns.
- **Solar variability:** Variations in solar radiation, including fluctuations in solar radiation and sunspot activity, influence Earth's climate. While changes in solar output are relatively small compared to greenhouse gas-induced warming, variations in solar radiation can still impact climate patterns, particularly over long time scales.
- **Volcanic Activity:** Major volcanic eruptions release ash and gasses, including sulfur dioxide (SO_2), into the atmosphere. These aerosols can reflect sunlight, temporarily cooling the planet's surface and leading to short-term climate fluctuations. However, the long-term impact of volcanic activity on climate is relatively minor compared to other factors.

- **Ocean Circulation:** The oceans regulate Earth's climate through processes such as heat storage, circulation patterns (e.g., the Gulf Stream), and carbon dioxide absorption acting as Carbon sinks.
  - Changes in ocean circulation, driven by factors such as temperature gradients and wind patterns, can influence regional and global climate patterns over both short and long term scales.
  - For instance, Ocean currents function as a conveyor belt, moving warm water and precipitation from the equator towards the poles and cold water from the poles back to the tropics. In doing so, they play a crucial role in regulating global climate by balancing the uneven distribution of solar radiation reaching Earth's surface.

Mount Tambora Eruption (1815): Case Study

- **Unprecedented Power:**
  - Ranks among **history's mightiest volcanic eruptions.**
  - Discharged ash, gases, and aerosols soaring over 43 km.
- **Global Fallout:**
  - Generated an extensive volcanic ash cloud.
  - Released sulfur dioxide inducing a global cooling effect.
- **Cooling Mechanism:**
  - Sulfur dioxide mingled with water vapor.
  - Formed light-reflecting sulfate aerosols.
  - Resulted in the infamous **"Year Without a Summer"** in 1816.
- **Global Impact:**
  - Global repercussions included temperature drops and disrupted weather patterns.
  - Instances of crop failures, summer snowfall, and frost in the Northern Hemisphere.
- **Takeaways:**
  - Underscores the potential climatic influence of major volcanic events.
  - Highlights the intricate interplay between geological and atmospheric processes on a global scale.

Radiative Forcing

Radiative forcing refers to the difference between the incoming solar radiation absorbed by the Earth and the outgoing infrared radiation emitted by the Earth. It serves as a measure of the influence that various factors, both natural and human-induced, have on altering the balance of energy in the Earth's atmosphere.

- **Positive Radiative Forcing** implies an increase in the amount of energy absorbed by the Earth, leading to a warming effect, while **negative radiative forcing** indicates a decrease in absorbed energy, resulting in a cooling effect.
- **Positive Radiative Forcing Factors:** include greenhouse gases like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor, as well as human activities such as deforestation and industrial emissions. These gases trap heat in the atmosphere, contributing to the enhanced greenhouse effect and global warming.
- **Negative Radiative Forcing Factors:** include aerosols and certain types of particulate matter, reflect solar radiation back into space, thereby reducing the amount of energy absorbed by the Earth's surface and exerting a cooling influence.

Understanding radiative forcing is crucial for assessing the drivers of climate change and formulating effective mitigation strategies to address its impacts. By quantifying the radiative forcing associated with different factors, scientists can better comprehend the complex interactions within the Earth's climate system and predict future changes with greater accuracy.

These theories, among others, contribute to our understanding of the complex and dynamic nature of Earth's climate system. Ongoing research and observations continue to refine and expand our knowledge of climate change mechanisms and their interactions.

The **nine** planetary boundaries include:

- Climate change
- Biodiversity loss
- Biogeochemical flows
- Ocean acidification
- Land use change
- Freshwater use
- Ozone depletion
- Atmospheric aerosols
- Chemical pollution

THE GREENHOUSE EFFECT

- The greenhouse effect refers to the trapping of heat near the Earth's surface by substances called 'greenhouse gases.' Visualize these gases as a snug blanket surrounding our planet, which helps retain a warmer temperature than it would naturally have.

- Greenhouse gases include carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons, and water vapor. Water vapor, sensitive to temperature shifts, is termed a 'feedback' as it intensifies the impact of factors initiating warming.
- Greenhouse gases are crucial for maintaining the delicate balance between cooling and warming on Earth.
- Without the natural greenhouse effect they provide, the average temperature of the Earth's surface would be approximately -19°C, compared to the current value of 15°C. This absence of greenhouse gases would render the planet frozen and devoid of life.

What is a Greenhouse?

In a greenhouse, glass walls allow sunlight to enter and warm the interior, but it also traps the heat inside, creating a warmer environment than the surrounding air. Similarly, greenhouse gases in the Earth's atmosphere allow sunlight to penetrate and warm the surface, but they also trap some of the heat, preventing it from escaping back into space.

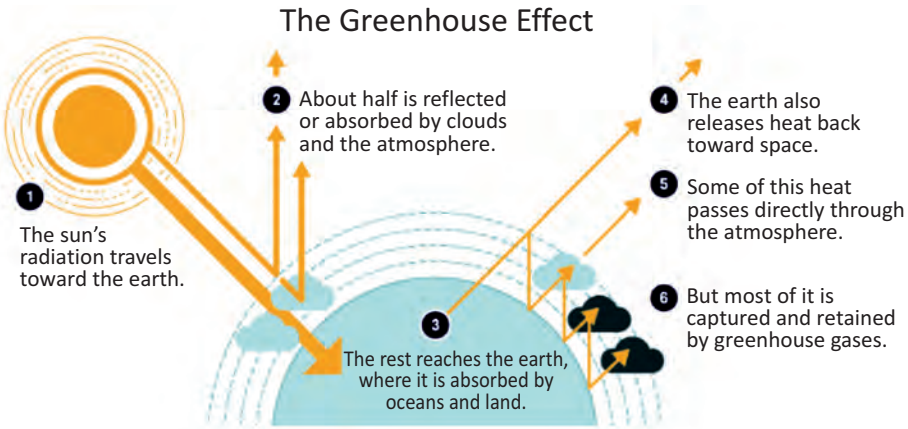

The Greenhouse Effect
1 The sun's radiation travels toward the earth.
2 About half is reflected or absorbed by clouds and the atmosphere.
3 The rest reaches the earth, where it is absorbed by oceans and land.
4 The earth also releases heat back toward space.
5 Some of this heat passes directly through the atmosphere.
6 But most of it is captured and retained by greenhouse gases.

Fig. 11.3: Green House and Green House Effect

Mechanism of the Greenhouse Effect

- **Incoming Energy:** The Sun emits high-energy short wavelengths of energy that reach Earth through the atmosphere due to its high temperature.
- **Absorption:** Approximately 30% of the Sun's energy is reflected back into space by the atmosphere, clouds, and Earth's surface, while the remaining energy is absorbed into Earth's system.
- **Emission:** Earth emits energy back into the atmosphere in the form of longer-wavelength infrared radiation, as it is cooler than the Sun.
- **Role of Greenhouse Gases:** Greenhouse gases in the atmosphere absorb much of the infrared radiation emitted by Earth's surface, preventing it from escaping into space. These gases then re-emit this energy in all directions, warming the surface and lowering the atmosphere.
- **Human Influence:** Over the past two centuries, the concentration of greenhouse gases in the atmosphere has significantly increased, primarily due to human activities such as burning fossil fuels and deforestation.
  - This increase enhances the natural greenhouse effect by trapping more energy emitted by Earth, leading to an increase in surface temperature.

Natural Vs Human-Enhanced Greenhouse Effect

Aspect	Natural Greenhouse Effect	Human-Induced Greenhouse Effect
Definition	The process where certain gases in the Earth's atmosphere trap heat from the sun, preventing it from escaping back into space.	Occurs when human activities release additional greenhouse gases into the atmosphere, intensifying the greenhouse effect.
Cause	Naturally occurring greenhouse gases, such as water vapor, carbon dioxide, methane, nitrous oxide, and ozone, trap heat in the atmosphere.	Human activities, including burning fossil fuels, deforestation, and industrial processes, release additional greenhouse gases into the atmosphere.
Effect on Climate Change	Plays a vital role in maintaining Earth's temperature within a habitable range, allowing life to thrive.	Exacerbates the natural greenhouse effect, leading to increased heat retention in the atmosphere, global warming, and climate change.

Significance of Natural Greenhouse Effect

- The natural greenhouse effect regulates Earth's temperature, ensuring habitability by trapping heat in the atmosphere.
- It maintains a stable climate, vital for supporting diverse ecosystems and human life.
- This process balances energy input from the sun with outgoing radiation, stabilizing temperatures within a suitable range.
- Additionally, it influences the water cycle, impacting evaporation, cloud formation, and precipitation patterns.
- Over time, the natural greenhouse effect has fostered climate stability, allowing ecosystems to adapt and evolve. Preserving this delicate balance of greenhouse gases is essential to safeguarding Earth's habitable environment.

Greenhouse Gases (GHG)

Greenhouse gases are atmospheric gases, occurring naturally or produced by human activities, that trap and release infrared radiation. These gases comprise Carbon Dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Ozone (O_3), Water Vapor (H_2O), and certain synthetic compounds such as Chlorofluorocarbons (CFCs).

Let us examine each of these gases in detail.

Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) is the predominant greenhouse gas released as a result of human activities. Naturally occurring, CO_2 is part of the Earth's carbon cycle, which involves the continuous exchange of carbon among the atmosphere, oceans, soil, plants, and animals.

- Human activities have disrupted the carbon cycle by both increasing CO_2 emissions into the atmosphere and diminishing natural CO_2 sinks, such as forest, which remove CO_2 from the atmosphere.
- Although CO_2 emissions originate from various natural sources, the rise in atmospheric CO_2 levels since the industrial revolution is primarily attributed to human activities.

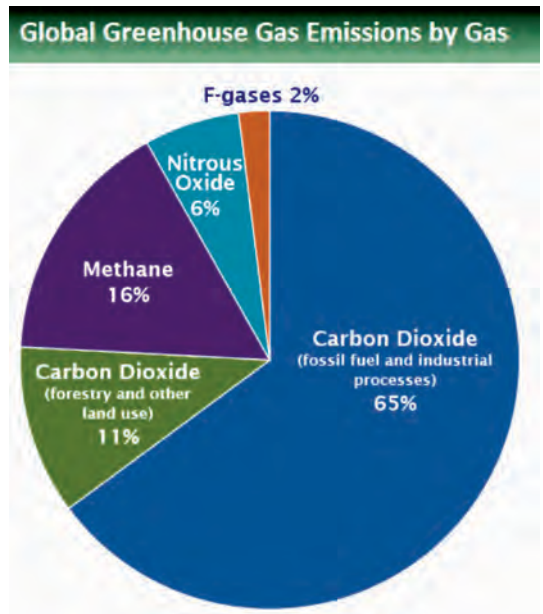

Global Greenhouse Gas Emissions by Gas
F-gases 2%
Nitrous Oxide 6%
Methane 16%
Carbon Dioxide (fossil fuel and industrial processes) 65%
Carbon Dioxide (forestry and other land use) 11%

Fig. 11.4: Global Green House Emissions

Sources of CO_2: The main sources of carbon dioxide (CO_2) emissions are:

- Burning fossil fuels for energy production and transportation.
- Deforestation and land use changes.
- Industrial processes, including cement production and chemical manufacturing.
- Waste management, such as landfills and waste incineration.
- Agricultural activities, including livestock digestion and rice cultivation.
- Biomass burning for cooking and heating.

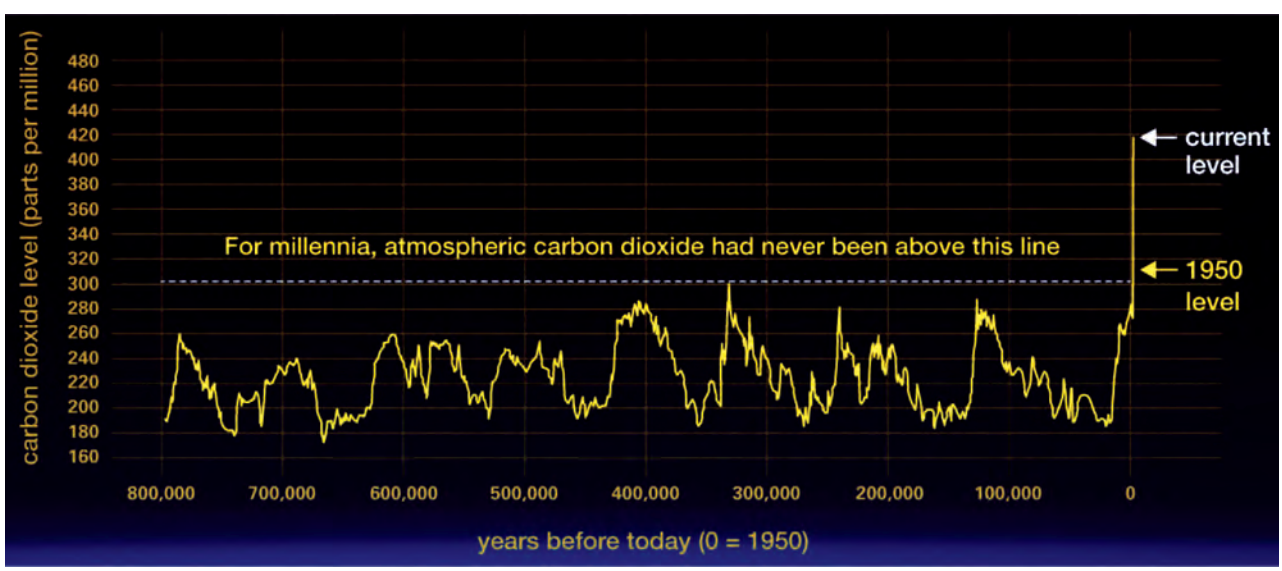


Fig. 11.5: CO_2 Levels over 800000 years

Methods to Reduce CO_2: They include transition to renewable energy, efficiency, public transportation, promoting electric vehicles, afforestation and sustainable agriculture among others. Some key strategies include:

- **Transitioning to Renewable Energy:** Investing in renewable energy sources such as solar, wind, and hydroelectric power can significantly reduce CO_2 emissions from electricity generation.
- **Improving Energy Efficiency:** Implementing energy-efficient technologies and practices in buildings, transportation, industry, and appliances can lower energy consumption and reduce CO_2 emissions.
- **Promoting Sustainable Transportation:** Encouraging the use of public transportation, walking, biking, and electric vehicles can help decrease CO_2 emissions from transportation.
- **Reforestation and Afforestation:** Planting trees and restoring forests can capture and store CO_2 from the atmosphere, mitigating emissions and enhancing carbon sequestration.
- **Carbon Capture and Storage (CCS):** Implementing technologies to capture CO_2 emissions from industrial processes and power plants and storing them underground can prevent CO_2 from entering the atmosphere.

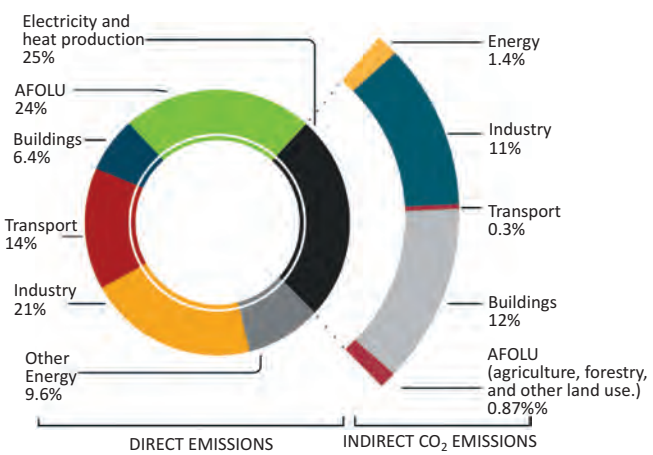


Fig. 11.6: Direct and Indirect CO_2 Emissions

- **Sustainable Agriculture:** Adopting practices such as conservation tillage, crop rotation, and agroforestry can reduce CO_2 emissions from agricultural activities.
- **Waste Reduction and Recycling:** Reducing waste generation, increasing recycling rates, and improving waste management practices can minimize CO_2 emissions from landfills and waste incineration.
- **Policy Support:** Implementing policies such as carbon pricing, emissions trading systems, renewable energy incentives, and energy efficiency standards can create a favorable environment for reducing CO_2 emissions.

By implementing these strategies and fostering global cooperation, it is possible to significantly reduce CO_2 emissions and mitigate the impacts of climate change.

Changing Trend in Atmospheric Carbon Dioxide

Every year, human activities contribute to the release of more carbon dioxide into the atmosphere, surpassing natural removal processes. This continual input has led to a notable increase in atmospheric carbon dioxide levels over time.

- **Historical Context:** Prior to the Industrial Revolution, CO_2 levels were consistently around 280 ppm for almost 6,000 years of human civilization.
- **Recent Records:** In 2022, the global average concentration of carbon dioxide reached a new record high of 417.06 ppm, according to NOAA's Global Monitoring Lab. This marked the 11th consecutive year of increases exceeding 2 ppm.
- **Current Levels:** Presently, atmospheric carbon dioxide levels stand at approximately 50% higher than pre-Industrial Revolution levels. The annual increase in atmospheric carbon dioxide over the last six decades has been approximately 100 times faster than natural increases observed during previous periods.
- **Impact on the Ocean:** The ocean has absorbed a significant amount of carbon dioxide from the atmosphere, resulting in a decrease in pH by 0.1 unit. This corresponds to a 30% increase in acidity, posing a threat to marine ecosystems and biodiversity.

The relentless rise in atmospheric carbon dioxide levels due to human activities underscores the urgent need for concerted efforts to mitigate climate change and its adverse effects on the environment, including ocean acidification and its repercussions on marine life.

Water Vapor

- Abundant Greenhouse Gas: Water vapor stands as the most abundant greenhouse gas in the Earth's atmosphere, playing a crucial role in the natural greenhouse effect.

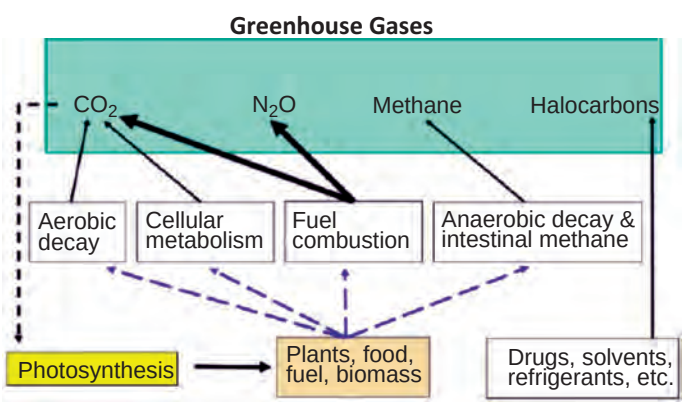


Fig. 11.7: Greenhouse Gases

- **Climate Influence:** Its concentration exhibits wide variations influenced by factors such as temperature and humidity, making water vapor a vital component for understanding short-term weather patterns and climate variability.

- **Role in Climate System:** Water vapor acts both as a driver and a feedback mechanism in the Earth's climate system. The atmosphere's warming results in an increased capacity to hold water vapor, leading to a feedback loop that intensifies the greenhouse effect.

Nitrous Oxide (N_2O)

- **Natural Occurrence:** Nitrous oxide is a natural component of the Earth's nitrogen cycle, originating from various natural sources.
- **Greenhouse Gas Impact:** Despite its smaller atmospheric presence compared to carbon dioxide (CO_2), nitrous oxide is a potent greenhouse gas that significantly contributes to global warming.
- **Sources:** Nitrous oxide emissions arise from various sources, including agricultural activities, industrial processes, combustion, and waste management.
- **Greenhouse Effect Contribution:** Due to its long atmospheric lifetime (approximately 114 years) and high heat-trapping ability, nitrous oxide is responsible for around 6% of total greenhouse gas-induced warming.

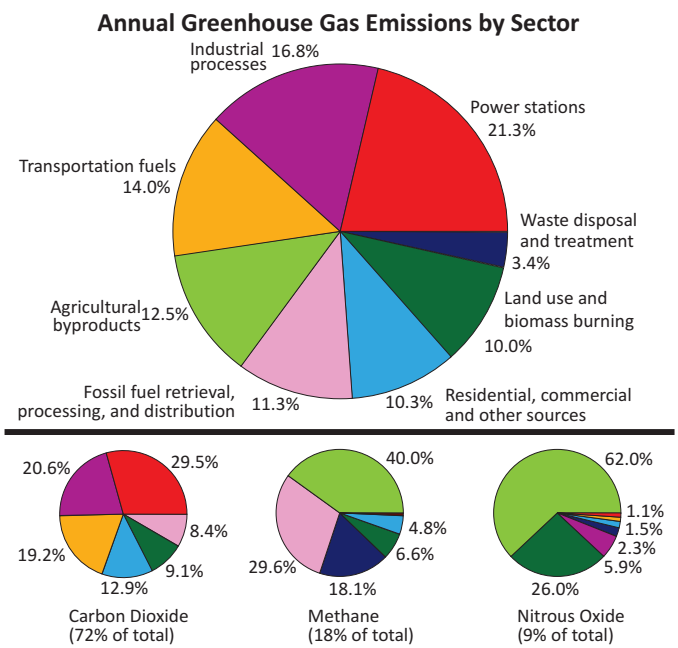


Fig. 11.8: Annual Greenhouse Gas Emissions by Sector

Methane (CH_4)

- Methane is a colorless, odorless gas emitted by natural sources such as wetlands, as well as human activities such as leakage from natural gas systems and the raising of livestock. Additionally, landfills, agriculture, and permafrost melt also emit methane.
- **Human-Related Emissions:** Approximately 60% of current methane flux from land to the atmosphere stems from human-related activities, with agriculture being the primary contributor.

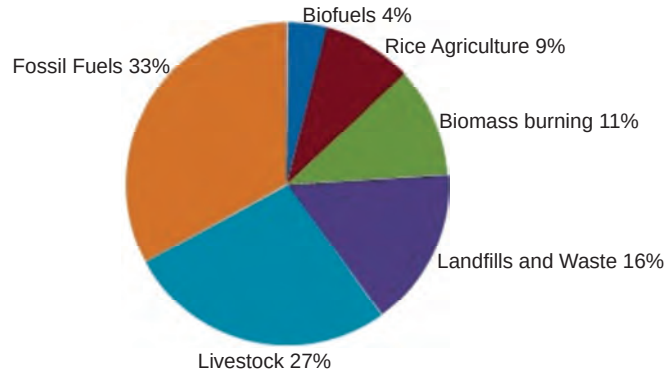


Fig. 11.9: Methane Emission By Source

- **Concentration Increase:** Over the past 200 years, atmospheric methane concentrations have steadily increased, more than doubling during this period.
- **Atmospheric Residence Time:** The atmospheric residence time of methane is approximately 8 years, indicating its relatively short-term impact on climate.
- **Removal Process:** Methane is primarily removed through **oxidation** – a chemical reaction with **hydroxyl radicals (OH)** in the presence of sunlight. This process converts methane into less potent greenhouse gases like carbon dioxide (CO_2) and water vapor (H_2O).

Fluorinated Gases

They are emitted through a variety of industrial processes such as aluminium and semiconductor manufacturing & substitution for ozone depleting substances.

Chlorofluorocarbons (CFCs)

- **Anthropogenic Origin:** CFCs are exclusively anthropogenic, generated solely by human activities rather than natural processes.
- **Ubiquitous Usage:** Commonly known for their use as refrigerants, aerosol propellants, and industrial solvents, CFCs, while less prevalent in the atmosphere than CO_2, have a more potent warming effect.

Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and SF_6

- **Industrial Alternatives:** Developed as alternatives to ozone-depleting chlorofluorocarbons, HFCs and PFCs are also anthropogenic.
- **Atmospheric Impact:** Despite being emitted in smaller quantities, their increasing atmospheric concentrations contribute significantly to the greenhouse effect.
- **Diverse Applications:** Used in various industrial processes such as refrigeration, air conditioning, semiconductor manufacturing, and electrical transmission equipment like circuit breakers.

Aerosols

- Aerosols, comprising suspended particulate matter in the atmosphere, encompass a wide range of solid particles and liquid droplets. They originate from both natural and anthropogenic sources and have significant implications for climate and weather patterns.

- **Natural Occurrence:** Aerosols occur naturally from sources like volcanic eruptions, wildfires, windblown dust, and ocean emissions. They include dust particles, sea salt, volcanic ash, and biological aerosols such as pollen and spores.
- **Climate Impact:** Despite their short atmospheric lifespans, aerosols influence climate by reflecting sunlight back into space, potentially causing a cooling effect. However, they should not be relied upon as a long-term solution to counteract greenhouse warming.
- **Types of Aerosols:**
  - **Primary Natural Aerosols:** Directly emitted into the atmosphere from natural sources like sea spray, dust, and volcanic emissions.

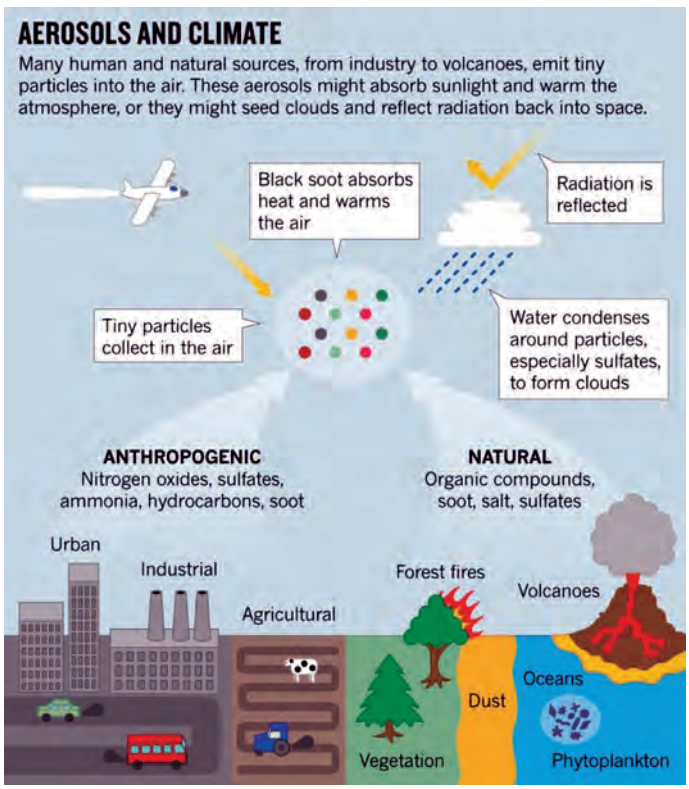

AEROSOLS AND CLIMATE
Many human and natural sources, from industry to volcanoes, emit tiny particles into the air. These aerosols might absorb sunlight and warm the atmosphere, or they might seed clouds and reflect radiation back into space.
Black soot absorbs heat and warms the air
Radiation is reflected
Tiny particles collect in the air
Water condenses around particles, especially sulfates, to form clouds
ANTHROPOGENIC
Nitrogen oxides, sulfates, ammonia, hydrocarbons, soot
NATURAL
Organic compounds, soot, salt, sulfates
Urban
Industrial
Agricultural
Forest fires
Volcanoes
Dust
Oceans
Vegetation
Phytoplankton

Fig. 11.10: Aerosols and Climate

  - **Secondary Natural Aerosols:** Formed through chemical reactions of natural gases, including sulfate and nitrate particles.
  - **Primary Anthropogenic Aerosols:** Emitted from human activities such as black carbon from industrial processes and organic carbon from vehicle exhaust.
  - **Secondary Anthropogenic Aerosols:** Result from chemical reactions involving human-released gases like ammonium sulfate and nitrate.
- **Concentrations:** Aerosols are predominantly concentrated in the lower atmosphere but can be dispersed over considerable distances. They impact weather and climate by influencing cloud formation, modifying albedo, and contributing to phenomena like urban smog.
- Aerosols are dynamic components of the atmosphere with diverse origins and significant climate impacts. Understanding their role is essential for addressing climate change and its associated challenges.

Types of Carbon Categories

- **Purple:** Carbon extracted from the atmosphere or industrial emissions.
- **Blue:** Carbon sequestered in ocean plants and sediments.
- **Teal:** Carbon stored in freshwater and wetland environments.
- **Green:** Carbon stored in terrestrial plants.
- **Black:** Carbon emitted through the combustion of fossil fuels.
- **Gray:** Carbon released from industrial emissions.
- **Brown:** Carbon released by incomplete combustion of organic matter.
- **Red:** Carbon released through biological particles on snow and ice, reducing albedo.

IGNITE YOUR MIND

The Greenhouse Gas Game: Earth as a Terrarium
Imagine Earth as a giant terrarium. Invisible walls of gas trap heat inside, keeping things warm and cozy. But what happens when human activities disrupt this delicate balance, turning the terrarium into a furnace?

GLOBAL WARMING POTENTIAL

Global Warming Potential (GWP) is a measure of how much heat a greenhouse gas traps in the atmosphere over a specific period, usually 100 years, compared to carbon dioxide (CO_2). It is a relative scale where CO_2 has a GWP of 1 by definition. GWP allows different greenhouse gases to be compared based on their ability to contribute to global warming over a specified timeframe.

Here are the approximate GWPs for some common GHGs:

- **Water Vapor (H_2O):** Water vapor is not typically assigned a GWP because its concentration in the atmosphere varies greatly and its lifetime is relatively short.
- **Methane (CH_4):** Methane has GWP more than 20 times higher than CO2 for a 100 year timescale. However, the lifetime of Methane is 12 years.
- **Nitrous Oxide (N_2O):** Nitrous oxide has a GWP 310 times that of CO2, for a 100 year timescale. However, the lifetime of Nitrous oxide is nearly 120 years.
- **Chlorofluorocarbons (CFCs), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs):** GWPs vary depending on the specific compound, but they can range from several hundred to several thousand over 100 years.

- **Sulfur Hexafluoride (SF_6):** GWP of approximately 23,500 over 100 years, with a lifespan of 3,200 years.

It's important to note that these values are approximate and can vary depending on the time period considered and other factors. A higher GWP indicates greater warming potential for a gas. For instance, N_2O has a 100-year GWP of about 310, implying that N_2O will cause 310 times more warming than an equivalent mass of carbon dioxide over a 100-year period.

- CFCs, HFCs, PFCs, and SF_6 are referred to as high-GWP gases because, relative to their mass, they have a much greater capacity to trap heat compared to CO_2.

Major Greenhouse Gases

Gas	Sources	Removal	GWP	Lifetime
Water Vapor (H_2O)	Evaporation- Oceans, rivers etc; Transpiration-plants, soil; Volcanic eruptions, respiration from animals; Not directly emitted by humans	Precipitation, condensation, deposition, sublimation	Excluded from GWP definition	Days to weeks
Carbon Dioxide (CO_2)	Oceans, respiration, volcanic eruptions; fossil fuel combustion, transportation, agriculture(livestock, rice cultivation), Respiration, Human activities	Carbon sequestration, ocean absorption, Photosynthesis, Chemical Weathering	1	50 - 200 years
Methane (CH_4)	Wetlands, Livestock manure, Oceans, Enteric Fermentation(microbial digestion in ruminants), Biomass Burning, human activities (agriculture, industries)	Oxidation, soil absorption, soil uptake, chemical sinks, stratospheric loss(Photolysis by UV-rays).	28	10 - 15 years
Nitrous Oxide (N_2O)	Nitrogen cycle, human activities, fertiliser application, landfills, transportation, wetlands, combustion of fossil fuels	Microbial consumption, chemical reactions(Photolysis), soil uptake, ocean uptake	265	120 years
SF_6	magnesium, copper and aluminium manufacturing, electrical transmission	Destruction by sunlight	23,500	3,200 years
CFC-12 (CCl_2F_2)	Industrial products (refrigerants, aerosols); Anthropogenic origin	Destruction by sunlight	10,200	140 years
CF_4 (CF_4)	Industrial processes; Limited natural sources	Unknown	6,630	50,000 years
HCFC-22 ($CHClF_2$)	Industrial processes; Limited natural sources	Decomposition in atmosphere	1,760	12 years

Note: GWPs vary based on region and sources. Hence, those mentioned in the table are approximates.

EVIDENCES OF CLIMATE CHANGE AND GLOBAL WARMING

EVIDENCE of climate change and global warming includes rising global temperatures, glacier retreat, sea level rise, ocean warming, extreme weather events, Arctic sea ice decline, ocean acidification, changes in phenology, shifts in species ranges, and consistency with climate models.

Rising Global Average Temperatures

- The IPCC's Sixth Assessment Report (AR6), released in 2021, indicated that the global average surface temperature increased by approximately 1.07°C (1.9°F) between 1850 and 2019. This stands at 1.17°C as of December 2023, according to NASA.
- A special IPCC report from 2018 highlighted human activities as the primary cause of a global temperature rise of 0.8 to 1.2°C (1.4 to 2.2°F) since preindustrial times, with most of the warming in the latter half of the 20th century attributed to human influence.

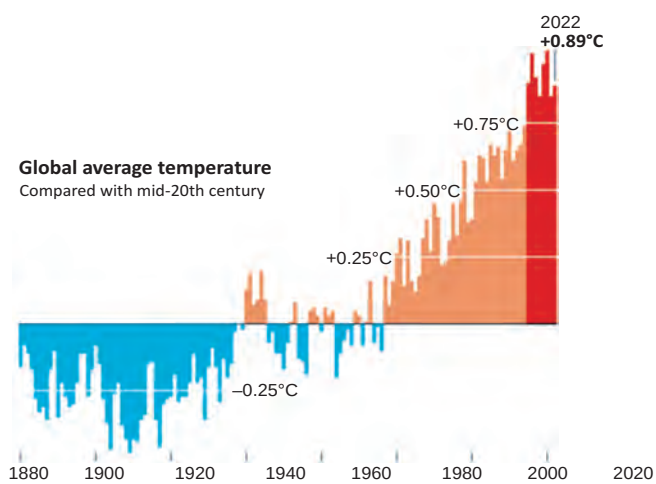


Fig. 11.11: Global Average Temperature

- 2023 has been the warmest year on record, with a global average temperature of 14.98°C, higher than the previous highest annual value in 2016 by 0.17°C

Retreating Glaciers

Retreating glaciers globally, glaciers are diminishing and retracting. Remarkably, glacier recession and the thermal expansion of the ocean collectively contribute to 75% of the current observed sea level rise. Due to their small size and rapid response times, glaciers promptly react to shifts in air temperature and precipitation.

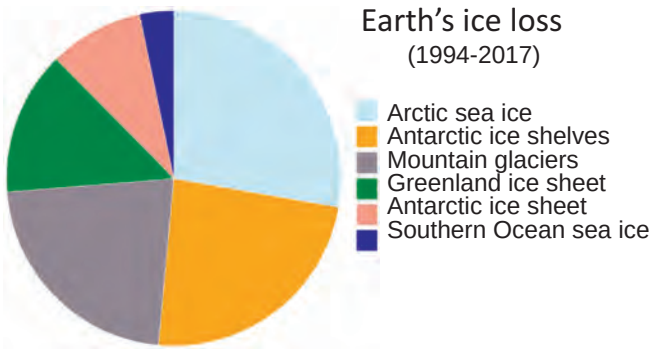


Fig. 11.12: Earth's Ice Loss

- The iconic snows of Kilimanjaro have dwindled by over 80% since 1912.
- Glaciers in India's Garhwal Himalayas are receding so rapidly that experts anticipate the virtual disappearance of most central and eastern Himalayan glaciers by 2035.
- Arctic sea ice has notably thinned in the past 50 years, with its extent shrinking by approximately 10% in the last three decades.
- NASA's laser altimeter readings consistently reveal the diminishing edges of Greenland's ice sheet. Spring freshwater ice breakup in the Northern Hemisphere now occurs nine days earlier than 150 years ago, while autumn freeze-up happens ten days later.
- Thawing permafrost has led to ground subsidence exceeding 15 feet (4.6 meters) in parts of Alaska. From the Arctic to Peru, and from Switzerland to Indonesia's equatorial glaciers of Man Jaya, vast ice fields, massive glaciers, and sea ice are vanishing at an alarming rate.

Sea Level Rise

- According to the United Nations, around 40% of the world's population lives within 100 kilometers of a coastline, potentially impacting nearly three billion individuals with sea level changes.
- Since 1880, the global average sea level has risen by 8 to 9 inches (21 to 24 centimeters). In 2022, the global average sea level hit a new record high, exceeding 1993 levels by 101.2 mm (4 inches).
- The increasing water level primarily results from a combination of melted water from glaciers and ice sheets, along with the thermal expansion of seawater as it heats up.

GLOBAL SEA LEVEL

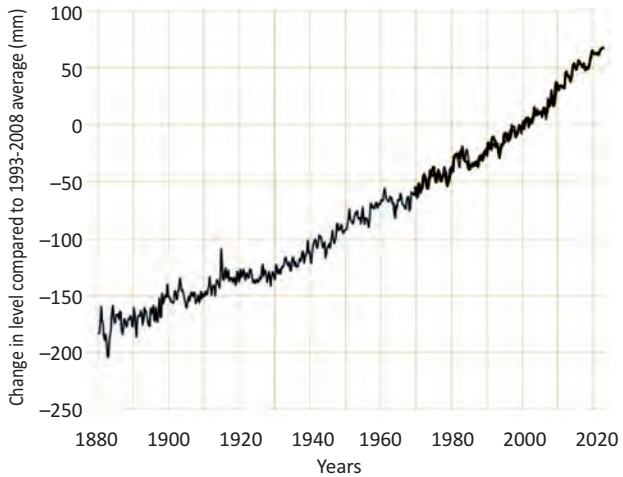


Fig. 11.13: Global Sea Level

Warming of The Ocean

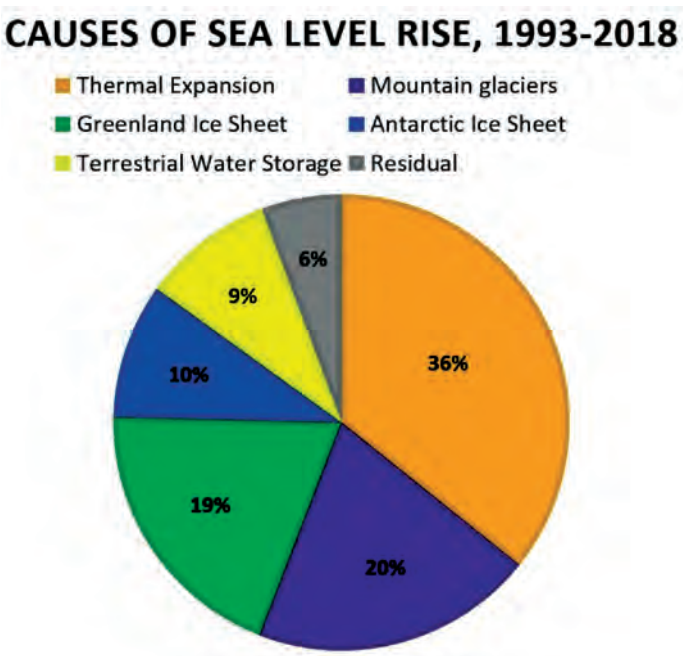


Fig. 11.14: Causes of Sea Level Rise

- Since 1971, the ocean has absorbed 90 percent of the surplus energy introduced into Earth's climate through the combustion of fossil fuels and other human activities.
- This heat is primarily absorbed by the ocean's surface layer, where the majority of marine life resides. According to the National Oceanic and Atmospheric Administration (NOAA), the upper 700 meters (2,300 feet) of the global ocean has experienced a warming of approximately 1.5°F since 1901.
- Additionally, researchers have recently discovered that the rate of warming in the top 6,500 feet of the ocean over the past few decades was approximately 40 percent greater than previously thought.

IGNITE YOUR MIND

Rising Seas, Sinking Cities: Submerged Landmarks Picture iconic coastal landmarks submerged, island nations disappearing beneath the waves. How is global warming causing sea levels to rise, and what are the potential consequences for humanity?

Extreme Weather Events

- As per The Council on Energy, Environment and Water (CEEW), the frequency, intensity, and unpredictability of extreme events have increased in recent decades.
- While India experienced 250 extreme climate events over 35 years from 1970 to 2005, it encountered 310 such weather events in just 15 years thereafter.
- The current surge in catastrophic climate events can be attributed to a mere 0.6 degrees Celsius temperature rise over the past century.
- India currently ranks as the 5th most vulnerable country globally in terms of extreme climate events and is poised to become the world's flood capital.

Ocean Acidification

- Ocean acidification is the continuous reduction in the pH of Earth's ocean water, triggered by the absorption of carbon dioxide (CO_2) from the atmosphere.
- As CO_2 dissolves in seawater, it creates carbonic acid, elevating the water's acidity.
- This phenomenon of ocean acidification has persisted for numerous decades and is predominantly fueled by the combustion of fossil fuels, leading to significant CO_2 emissions into the atmosphere.
- The acidity of ocean water has increased by about 30% since the Industrial revolution.

These impacts underscore the urgency for global climate action to mitigate and adapt to the consequences of climate change.

CAUSES OF CLIMATE CHANGE

Climate change is a complex phenomenon influenced by natural and anthropogenic (human-induced) factors. Understanding these causes is crucial for developing effective mitigation strategies to adapt to the changing climate.

Natural Causes

- **Solar Radiation Variability:** Natural variations in the sun's energy output, such as changes in solar radiation and sunspot cycles, can impact Earth's climate over long periods.
- **Volcanic Activity:** Volcanic eruptions release large amounts of ash, gases, and particles into the atmosphere. While these events can temporarily cool the climate, the long-term impact depends on the frequency and intensity of eruptions.
- **Orbital Changes (Milankovitch Cycles):** Milankovitch cycles, comprising eccentricity, obliquity, and precession, shape Earth's climate over millennia.
  - **Eccentricity** alters season lengths and solar radiation intake, currently trending towards a more circular orbit.
  - **Obliquity's** tilt angle affects season severity, with a decreasing tilt softening seasons.
  - **Precession** induces wobbles in Earth's axis and orbit, altering seasonal contrasts over roughly 23,000 years.

While vital for understanding past climate shifts like Ice Ages, these cycles cannot solely explain today's rapid warming, driven largely by human activities.

Anthropogenic Causes

Human activity, particularly the burning of fossil fuels and deforestation, is the main cause of current global climate change. This has led to unprecedented levels of greenhouse gases like carbon dioxide in the atmosphere, raising Earth's temperature by 1.9°F in the 20th century. The impacts of climate change, such as extreme weather events, disproportionately affect marginalized communities, despite their lesser contribution to emissions. Our energy generation, transportation, land use, and consumption patterns are the consistent drivers of climate change. According to IPCC, AR6, the anthropogenic causes are:

- **Greenhouse Gas Emissions:** Human activities, especially the burning of fossil fuels (coal, oil, and natural gas) for energy, deforestation, and industrial processes, release greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).
  - These gases trap heat in the atmosphere, leading to the enhanced greenhouse effect and warming of the planet.
- **Generating Power:** The generation of electricity and heat through fossil fuel combustion is a significant contributor to global emissions.
  - Despite the increasing use of renewable sources like wind and solar, a majority of electricity still comes from coal, oil, or gas, emitting greenhouse gases into the atmosphere.
- **Manufacturing Goods:** Industrial activities, including manufacturing and construction, produce emissions primarily from fossil fuel usage. From producing cement to electronics, these processes emit greenhouse gases and pollutants. Additionally, materials like plastics are derived from fossil fuels, making the manufacturing industry a major emitter.

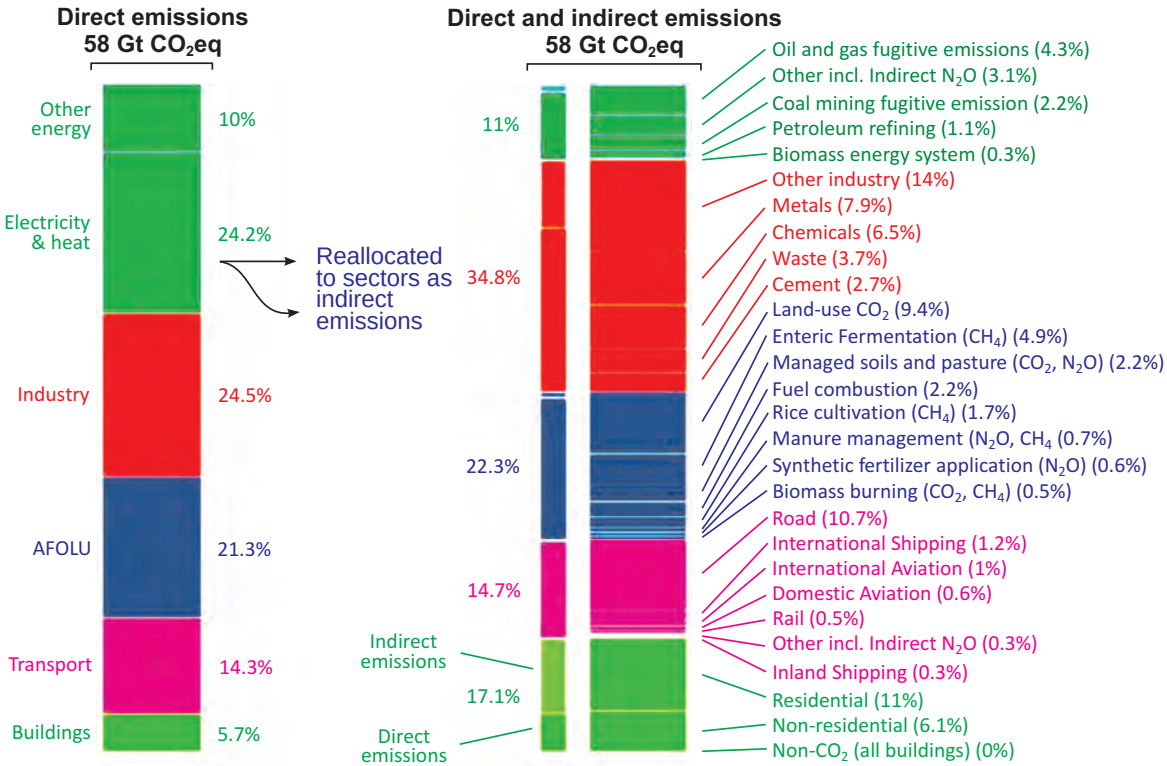


Fig. 11.15: Direct and Indirect CO_2 emissions

- **Deforestation:** Clearing forests for agriculture or other purposes releases stored carbon, contributing to emissions. Deforestation reduces the Earth's carbon absorption capacity, exacerbating climate change. Agriculture and land use changes, including deforestation, account for a significant portion of global emissions.
- **Transportation:** Fossil fuel-powered vehicles dominate transportation, emitting carbon dioxide and other greenhouse gases. Road vehicles, ships, and planes contribute to emissions, with transportation accounting for a significant portion of global energy-related carbon dioxide emissions.
- **Food Production:** Food production contributes to emissions through various activities like deforestation, livestock digestion, and the use of fertilizers. Energy-intensive processes in agriculture and fishing also emit greenhouse gases, making food production a substantial contributor to climate change.
- **Building Energy Use:** Residential and commercial buildings consume a large portion of global electricity, primarily sourced from coal, oil, and natural gas. The increasing demand for heating, cooling, and electricity in buildings contributes to rising emissions.
- **Consumption Patterns:** Individual consumption habits, including energy use, transportation choices, dietary preferences, and material consumption, significantly impact greenhouse gas emissions. The wealthiest individuals bear the greatest responsibility for emissions, highlighting the role of lifestyle choices in climate change.

While natural causes have influenced the Earth's climate over geological time scales, the current warming trend is primarily attributed to human activities, particularly the increased concentration of greenhouse gases in the atmosphere. Addressing anthropogenic causes is critical to mitigating the impacts of climate change.

HISTORICAL RESPONSIBILITY FOR CLIMATE CHANGE BY COUNTRIES

According to Carbon brief's analysis, some countries are more responsible than others for the warming of the world. The question of responsibility regarding carbon budget usage is crucial in climate justice discussions, addressing both historical emissions and actions to mitigate further warming.

Assigning responsibility is complex, primarily relying on cumulative national territorial emissions data. Each bar, represented by a national flag, indicates a country's cumulative emissions over time, color-coded by region.

- **United States:** The US, a vast nation, significantly contributed to emissions by clearing temperate forests for agriculture and fuel. Settlers' westward expansion for farming, guided by "manifest destiny," intensified emissions.
- **China:** China's rapid industrialization, fueled by coal since the early 2000s, propelled it to become the world's largest emitter. Its land-related emissions and economic boom dominate its cumulative CO_2 output

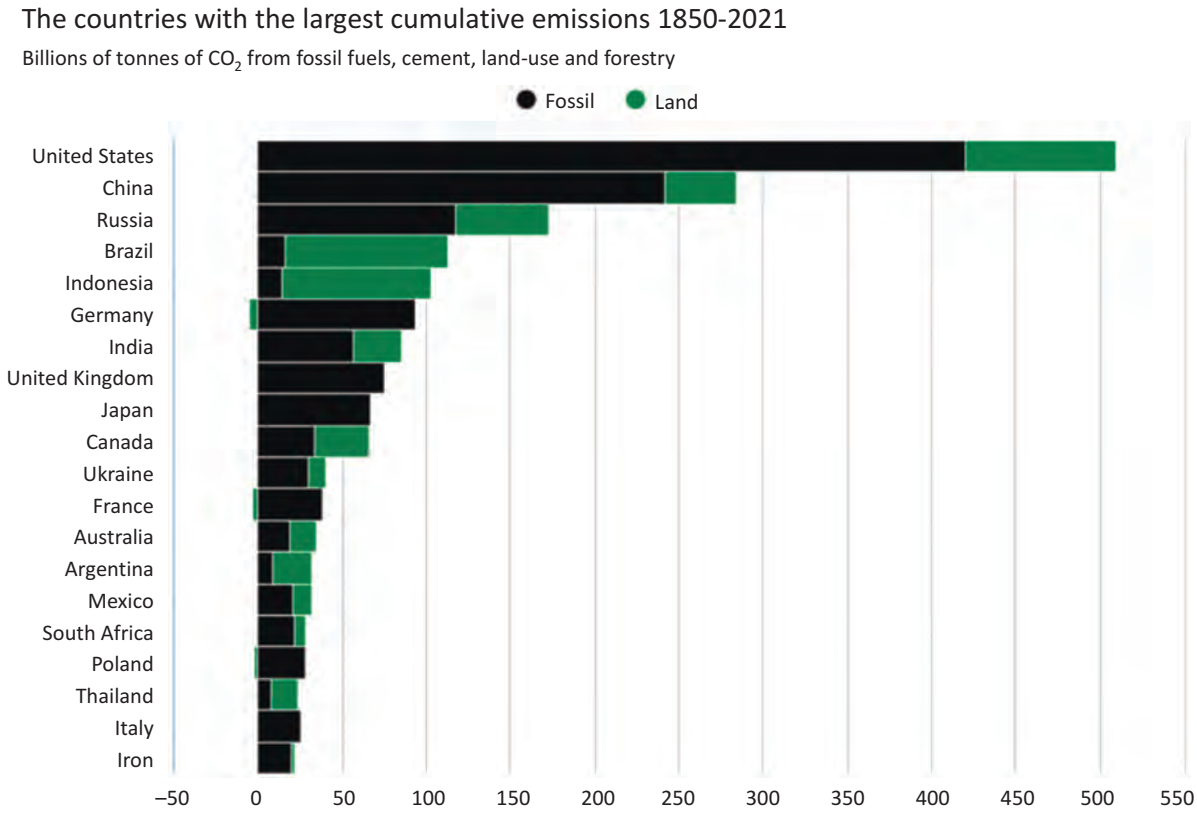


Fig. 11.16: The countries with the largest cumulative emission

- **Russia:** Russia follows the US in cumulative emissions, with a significant share of global CO_2 output, partly due to historical industrialization and territorial size.
- **Germany:** Germany's coal reliance places it among top emitters, though its land sectors have transitioned to CO_2 sinks with reforestation efforts.
- **Brazil and Indonesia:** Deforestation for cash crops like rubber and palm oil drove emissions, particularly since 1950, making Brazil and Indonesia significant historical emitters.
- **Japan and Canada:** Japan and Canada, ranking in the top 10 contributors, also have notable cumulative emissions, reflecting their industrialization and land-use patterns.
- **International Transport:** Aviation and shipping emissions, often excluded from national inventories, would rank high if treated as a "nation" in historical emissions.
- **India:** India's cumulative emissions, driven by land-use changes and forestry, place it just ahead of the UK in historical contributions.

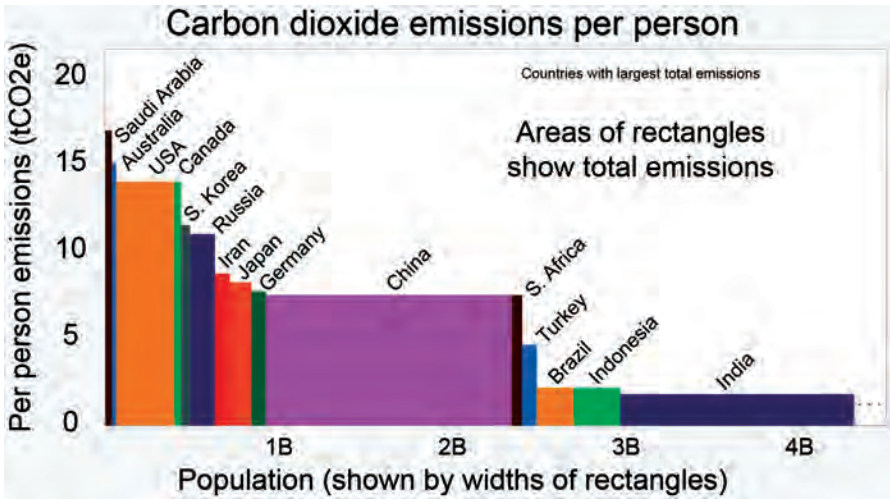


Fig. 11.17: CO_2 Emissions per person

- **Currently, India holds the position of the third-largest emitter of greenhouse gases globally, trailing behind China and the US,** with an annual emission of approximately 2.6 billion tonnes of CO_2 equivalent. **However, India's per capita emissions are significantly lower,** standing at merely 1.8 tonnes, a figure notably below the global average of 4.4 tonnes per capita.

Overall, understanding historical emissions sheds light on each country's contribution to climate change and underscores the importance of equitable mitigation efforts moving forward.

CONSEQUENCES OF CLIMATE CHANGE

Climate change consequences include rising temperatures, melting ice caps, sea level rise, extreme weather events, biodiversity loss, and disruptions to ecosystems and food systems. These changes pose threats to human health, infrastructure, agriculture, water resources, and socio-economic stability, exacerbating inequalities and vulnerabilities globally. Let us examine the consequences in detail:

Impact on Hydrological Cycle

Climate change profoundly affects the hydrological cycle, which regulates the distribution and availability of water on Earth's surface.

- **Changing precipitation patterns:** One significant impact is alterations in precipitation patterns, leading to changes in the timing, intensity, and geographic distribution of rainfall. As temperatures rise, the atmosphere can hold more moisture, resulting in increased evaporation rates from land and water bodies.
- **Changing atmospheric circulation patterns:** Coupled with altered precipitation patterns, it can lead to shifts in regional precipitation regimes, with some areas experiencing more frequent and intense rainfall events, while others face prolonged droughts.
- **Melting Ice Caps, Glaciers, and Snowpacks:** Contribute to rising sea levels and changes in river flows, impacting both coastal and inland water systems.
- **Reduced Freshwater Availability:** Loss of ice reduces freshwater availability in regions dependent on glacial meltwater, affecting ecosystems, agriculture, and communities relying on these water sources.
- **Increased Frequency of Extreme Weather Events:** Such as hurricanes, storms, and heatwaves, exacerbating flooding, erosion, and water contamination, disrupting hydrological systems.
- **Altered Hydrological Cycle:** Affects groundwater recharge rates and aquifer replenishment, leading to declining groundwater levels, saltwater intrusion, and reduced water availability.
- **Impact on Ecosystems and Biodiversity:** Shifts in temperature and precipitation patterns influence plant growth timing, disrupting habitats, altering species distributions, and leading to biodiversity loss. This will have cascading effects on ecosystem services and human well-being.

IGNITE YOUR MIND

Weather Gone Wild: Extreme Climate Events

Heatwaves scorching crops, floods displacing communities, and storms wreaking havoc – these are just glimpses of the extreme weather events becoming more frequent and intense due to climate change. How are these events impacting different parts of the world?

Impact on Food Security and Production Systems

- Climate change can significantly impact crop yields and the types of crops grown in certain regions by altering agricultural inputs such as water availability for irrigation, solar radiation affecting plant growth, and pest prevalence.
- Temperature increases caused by rising greenhouse gas emissions will affect crops differently across regions.
  - While moderate warming (1 to 3°C) is expected to benefit crop yields in temperate regions, it may have negative impacts on major cereal crops in lower latitudes, particularly in seasonally dry tropics.
  - Warming beyond 3°C is projected to negatively affect production globally. The IPCC's sixth Assessment Report in 2021 highlighted severe impacts of climate change on agricultural productivity, especially in the poorest countries.
- It predicted reduced crop yields in tropical and subtropical regions due to decreased water availability and changes in insect pest incidence.
- In South Asia, staple crops like rice, millet, and maize could experience losses exceeding 10% by 2030. Thawing snow is likely to increase arable land in high-latitude regions while reducing coastal arable land due to rising sea levels, erosion, and submergence of shorelines.
- A recent study by the International Commission for Snow and Ice reported rapid shrinking of Himalayan glaciers, which serve as vital dry-season water sources for Asia's major rivers.
- If current trends persist, these glaciers could disappear by 2035, posing significant water scarcity risks.
- Adverse effects of climate change on agricultural production in low-income developing countries, particularly in Asia and Africa, could jeopardize the livelihoods of rural populations and exacerbate food insecurity

IGNITE YOUR MIND

Food Chain Fumble: Disrupting the Web of Life

Climate change disrupts the intricate web of life, impacting agricultural productivity and jeopardizing food security. Can we untangle this web and ensure everyone has access to nutritious food in a changing climate?

The 'Climate-Smart Village' approach in India is a part of a project led by the Climate Change, Agriculture and Food Security (CCAFS), an international research programme. The project of CCAFS is carried out under the Consultative Group on International Agricultural Research (CGIAR).

On Population Displacement and Human Mobility

- Climate change has a significant impact on population displacement and human mobility. Rising sea levels, extreme weather events like storms and floods, droughts, wildfires, and changing ecosystems are all contributing factors.
- These events can force people to leave their homes due to loss of livelihoods, damage to infrastructure, and loss of habitable land.
- The resulting population displacement often leads to internal or cross-border migration, creating challenges for governments and communities in terms of managing resources, providing humanitarian assistance, and addressing social and economic implications.
- Climate change exacerbates existing vulnerabilities, particularly in regions already affected by poverty, conflict, and political instability.
- As climate change continues to worsen, population displacement and human mobility are expected to increase, necessitating proactive measures to mitigate its impacts and support affected communities.
- By the year 2050, climatic factors could potentially displace approximately 216 million individuals across six world regions (Sub-Saharan Africa, South Asia, Latin America, East Asia and the Pacific, North Africa, Eastern Europe and Central Asia). In 2020 alone, the region experienced over 9 million internal displacements, solidifying its status as the area with the highest number of new displacements attributable to climate change.
- The International Organization for Migration (IOM) reports that approximately 21.9 million people are internally displaced each year in the last decade due to storms, floods, wildfires, droughts, and extreme temperatures, with the number reaching 31.8 million in 2022. This figure is more than twice the number of displacements attributed to conflict.

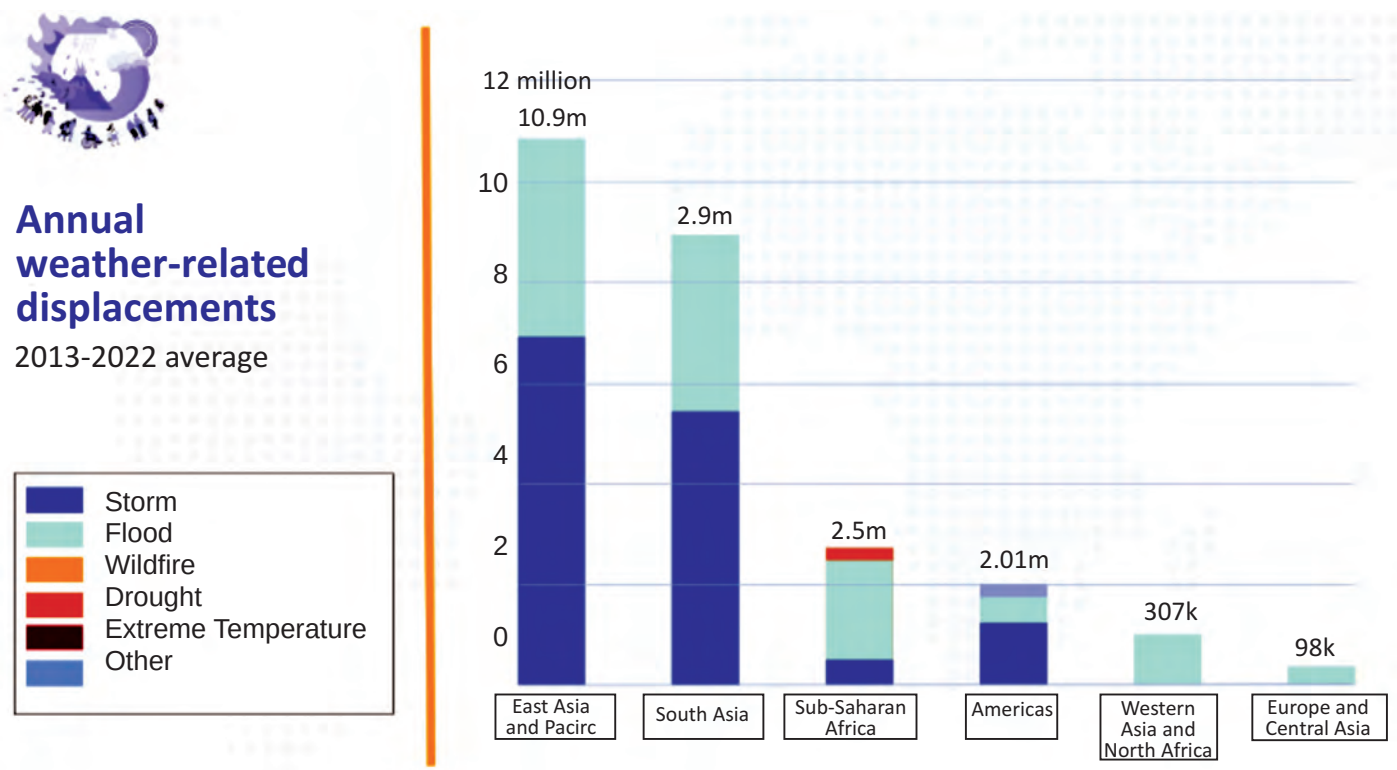


Fig. 11.18: Annual weather-related displacements

Impact on Human Health

Climate change has profound effects on public health, exacerbating existing health challenges and creating new ones. Here are some key impacts:

- **Heat-related Illnesses:** Increasing temperatures can lead to heat-related illnesses such as heatstroke, heat exhaustion, and dehydration, particularly among vulnerable populations like the elderly and outdoor workers.
- **Air Quality:** Climate change contributes to poor air quality through increased levels of air pollution, which can exacerbate respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD).
- **Vector-borne Diseases:** Climate change influences the distribution and behavior of disease-carrying vectors such as mosquitoes and ticks, leading to the spread of diseases like malaria, dengue fever, Zika virus, and Lyme disease to new regions.
- **Waterborne Diseases:** Changes in precipitation patterns and rising temperatures can affect water quality and availability, increasing the risk of waterborne diseases like cholera and diarrheal diseases.
- **Mental Health:** Climate-related disasters, displacement, and loss of livelihoods can cause psychological distress, anxiety, depression, and post-traumatic stress disorder (PTSD) among affected populations.
- **Extreme Weather Events:** Extreme weather events such as hurricanes, floods, and wildfires can cause injury, displacement, and mental health issues, as well as disrupt healthcare services and infrastructure.
- **Climate Refugees:** Population displacement due to climate change can lead to refugee crises, exacerbating health risks associated with overcrowded living conditions, poor sanitation and limited access to healthcare.

IGNITE YOUR MIND

Climate Refugees: The Exodus

Rising sea levels, extreme weather events, and resource scarcity are forcing people to flee their homes, becoming climate refugees. What challenges do they face, and how can we address this growing global issue?

On Economy

- Extreme weather, climate, and water-related events led to economic losses of nearly $1.5 trillion in the decade up to 2019, a significant increase from $184 billion in the 1970s, as reported by the World Meteorological Organization (WMO).

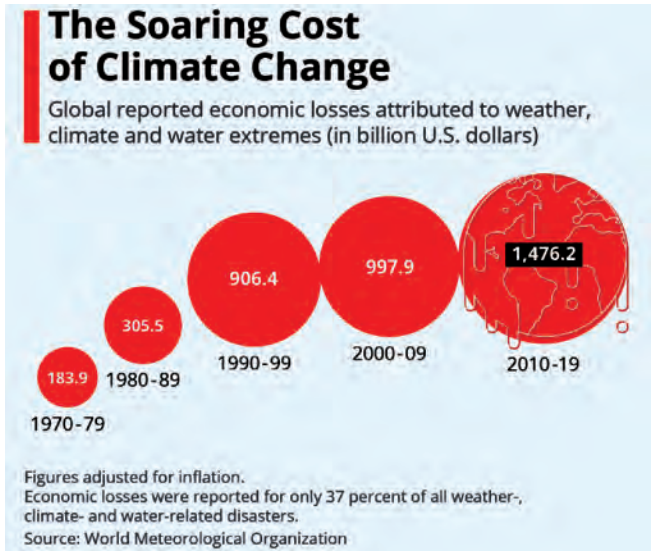


Fig. 11.19: The Soaring Cost of Climate Change

- The international community has faced challenges in making necessary progress on climate change, as highlighted in the World Economic Forum's Global Risks Report 2023.
- In Africa, disasters between 1970 and 2021 resulted in $43 billion in economic losses, with droughts accounting for 95% of fatalities.
- Europe experienced reported losses of $562 billion, with 8% of global disaster deaths occurring in the region. South America faced losses of $115.2 billion, while North America, Central America, and the Caribbean reported losses totaling $2 trillion.

On Energy Infrastructure and Supply

- Climate change poses significant challenges to energy infrastructure and supply systems. Rising temperatures, extreme weather events, and sea-level rise threaten the reliability and stability of energy infrastructure, including power plants, transmission lines, and distribution networks.
- Extreme weather events such as hurricanes, storms, and heat waves can damage energy infrastructure, leading to power outages and disruptions in energy supply.
  - For example, hurricanes can destroy power lines and substations, while heat waves can strain power plants, reducing their efficiency and causing them to shut down.
- Sea-level rise and coastal erosion also pose risks to energy infrastructure located in coastal areas, such as oil and gas facilities and nuclear power plants.
- Rising sea levels can inundate these facilities, leading to damage and potential release of hazardous materials into the environment. Furthermore, climate change can affect the availability and reliability of energy sources.
- Changes in precipitation patterns and water availability can impact hydropower generation while rising temperatures can reduce the efficiency of thermal power plants.

On Urban Areas

Climate change has profound impacts on urban areas, affecting various aspects of urban life, infrastructure, and public health. Here are some key impacts:

- **Increased Heat Stress:** Rising temperatures exacerbate heat stress in urban areas, leading to heat waves that pose serious health risks, particularly for vulnerable populations such as the elderly and those with pre-existing health conditions and for those living in slums, low cost unplanned neighbourhoods or on roads.
- **Urban Flooding:** Intense rainfall events and sea-level rise contribute to increased urban flooding, overwhelming drainage systems and causing property damage, disruption of services, and public safety risks.
- **Infrastructure Vulnerability:** Climate change puts urban infrastructure at risk, including transportation systems, water supply networks, and energy infrastructure. Extreme weather events can damage infrastructure, leading to service disruptions and economic losses.
- **Air Quality:** Climate change exacerbates air pollution in urban areas, with higher temperatures leading to increased ozone formation and the exacerbation of respiratory illnesses. Heatwaves also worsen air quality by promoting the formation of ground-level ozone and particulate matter.
- **Urban Biodiversity:** Climate change affects urban biodiversity, disrupting ecosystems and threatening plant and animal species. Urban green spaces, such as parks and gardens, provide critical habitats for wildlife and can help mitigate the impacts of climate change by providing cooling and flood mitigation.

On Rural Areas

- Rural households heavily rely on climate-sensitive resources like local water supplies and agricultural land, as well as activities such as farming and livestock husbandry.
- Climate change can diminish the availability of these resources, limiting options for consumption or trade. Land fertility may decline, affecting activities like basket-making, while reduced rainfall could curtail cropping seasons in regions like the Sahel in Africa.
- Fishery production may also decline, particularly in poorer African countries.
- Latin America's drier areas may experience increased soil salinity and desertification, further impacting crop productivity.

Impact on Physiography

Mountainous Region

Mountainous regions with significant elevation characterized by rugged terrain, high peaks and steep slopes. They are one of the most vulnerable ecosystems to climate change, experiencing a faster rate of warming than the global average. Here is an overview of the impact of climate change on mountainous regions, including recent data and examples:

- **Rising Temperatures:** They are causing accelerated warming in mountainous regions, leading to the rapid melting of glaciers and ice caps. These ice formations, crucial sources of freshwater for millions, are shrinking rapidly.
  - High-mountain areas have experienced a temperature increase double the global average, with the Gangotri Glacier in the Himalayas retreating over 1,700 metres since the 1930s.
  - Permafrost in these regions is thawing rapidly, up to 1 meter per year in some areas, leading to increased landslides, like those observed in the Alps.
- **Black Carbon and Glacial Melting:** Black carbon, emitted from fossil fuels and biomass burning, reduces snow and ice reflectivity, accelerating glacier melt.
  - Positive Feedback Loop: Deposited black carbon on glaciers exacerbates melting, releasing more black carbon, amplifying the process.
  - Global Climate Implications: This cycle contributes to Earth's overall warming, impacting sea levels, water resources, and ecosystems.
- **Impact on River System and Precipitation Resources:** Mountain river systems are highly vulnerable to climate change and human activities like pollution, hydropower development, and water withdrawals.
  - Climate change leads to altered precipitation patterns and more frequent cloudbursts, intensifying storms and prolonging droughts.
  - For instance, heavy precipitation events in the Himalayas increased by 50% since the 1950s, while Andean droughts rose by 20%.
  - IPCC predicts further extreme precipitation patterns, with some regions facing intensified rainstorms and others severe droughts.
- **Increased Intensity and Frequency of Natural Hazards and Disasters:** The IPCC's Sixth Assessment Report highlighted increased heavy precipitation events and cryosphere-related changes in mountain regions, leading to floods, landslides, and water scarcity.
  - Recent natural disasters in the Himalayan region include landslides in Sikkim in September 2022, causing infrastructure damage and casualties, and a flash flood in Chamoli, Uttarakhand, in October 2021, resulting in widespread destruction and loss of life.
  - The World Bank estimates that the economic costs of natural disasters in mountainous regions could reach US$500 billion per year by 2050.
  - The United Nations Environment Programme (UNEP) estimates climate change could trigger 20 million additional displacements from mountainous regions by 2050

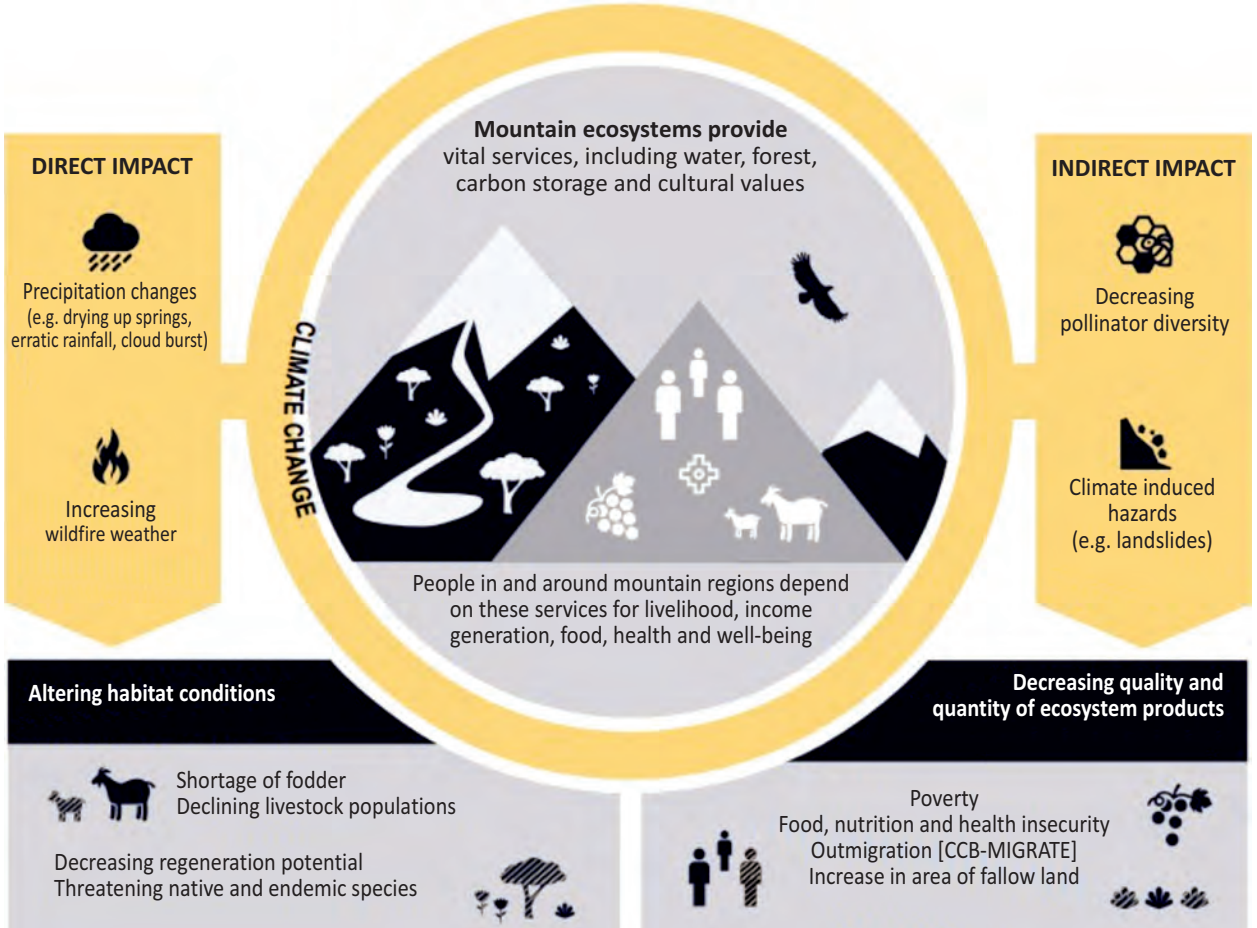

DIRECT IMPACT
Precipitation changes (e.g. drying up springs, erratic rainfall, cloud burst)
Increasing wildfire weather
Mountain ecosystems provide vital services, including water, forest, carbon storage and cultural values
CLIMATE CHANGE
People in and around mountain regions depend on these services for livelihood, income generation, food, health and well-being
INDIRECT IMPACT
Decreasing pollinator diversity
Climate induced hazards (e.g. landslides)
Altering habitat conditions
Shortage of fodder
Declining livestock populations
Decreasing regeneration potential
Threatening native and endemic species
Decreasing quality and quantity of ecosystem products
Poverty
Food, nutrition and health insecurity
Outmigration [CCB-MIGRATE]
Increase in area of fallow land

Fig. 11.20: Climate change Impact on Mountains

- **Impact on the Mountainous Ecosystem and Biodiversity:** Climate change is significantly affecting biodiversity in mountainous regions, with species struggling to adapt to shifting temperatures and precipitation patterns.
  - The IPCC's 6th assessment report warns of a rapid decline in biodiversity, with up to 25% of species facing extinction by the century's end.
  - For example, the Arctic fox is threatened as sea ice declines, impacting its hunting ability.
  - Changes in phenology and productivity are affecting medicinal and aromatic plants, crucial for ecosystem services and community livelihoods.
  - While some areas see positive impacts like increased mushroom productivity, others, like Himachal Pradesh's apple production, face declines, posing food security risks for mountain communities.

Karakoram Anomaly

The Karakoram Anomaly refers to a unique phenomenon observed in the Karakoram mountain range, which is part of the larger Himalayas in Central Asia. Unlike most other glaciers in the world, which have been shrinking due to global warming, glaciers in the Karakoram region have shown either stable or slightly advancing trends.

Several factors contribute to this anomaly:

- **High Precipitation:** The Karakoram region receives exceptionally high levels of precipitation, primarily in the form of winter snowfall. This increased snowfall replenishes glacier mass, offsetting the melting caused by rising temperatures.
- **Glacier Dynamics:** The complex topography and glacier dynamics in the Karakoram region, including the presence of debris cover on many glaciers, can insulate the ice from direct melting and slow down the rate of retreat.
- **Local Climate Patterns:** Local climate patterns, such as the interaction between the Indian summer monsoon and the westerlies, can create microclimates that differ from surrounding regions, influencing glacier behavior.

While the Karakoram Anomaly has provided some respite from glacier retreat in this particular region, it also underscores the complexities of glacier response to climate change.

Socio-Economic Impact on Mountainous Region

Mountain livelihood and poverty	Overview of key observed impacts on mountain communities and adaptation responses IPCC 6TH ASSESSMENT REPORT
Impact	❑ In some mountain areas, poverty rates may surpass those in other regions, with climate change exacerbating socioeconomic challenges. ❑ The World Bank predicts an additional 100 million people to be impoverished by 2030 due to climate change, particularly impacting mountainous regions. ❑ Economic growth in these areas is projected to decline by 2-4% per decade.
Responses and adaptation	Multifaceted approaches are underway: ❑ **Adaptive Farming Techniques:** Implement climate-resilient agricultural methods tailored to mountainous areas. ❑ **Livelihood Diversification:** Promote alternative income sources like ecotourism and sustainable forestry. ❑ **Community Participation:** Engage local communities in decision-making processes. ❑ **Preservation of Indigenous Knowledge:** Respect and integrate traditional practices.

On Coastal Regions

On Oceans

- ❑ The ocean serves as a crucial carbon sink, absorbing about 90% of excess heat caused by greenhouse gas emissions.
- ❑ This leads to ice melt, rising sea levels, marine heatwaves, and acidification. These changes impact marine biodiversity and coastal communities, affecting around 680 million people in low-lying areas.
- ❑ Additionally, nearly 2 billion people live in coastal regions in half of the world's megacities, with about 3.3 billion relying on fish for protein and close to 60 million employed in fisheries and aquaculture globally.

Atlantic Meridional Overturning Circulation

The Atlantic Meridional Overturning Circulation (AMOC) transfers warm water from the tropics to the North Atlantic, regulating global climate patterns.

- ❑ **Signs of Weakening AMOC:** Recent years have seen concerns over AMOC's weakening, observed over the past 15 years, with implications for global climate stability.
- ❑ **Factors Influencing AMOC:** Driven by fluctuations in water temperature and salinity, AMOC distributes heat and energy globally, influenced by factors like greenhouse gas-induced global warming.
- ❑ **Causes of AMOC Slowdown:** Global warming, spurred by greenhouse gas emissions, triggers changes in Arctic temperatures, freshwater influx from melting ice, and intensified rainfall, leading to AMOC slowdown.
- ❑ **Effects of AMOC Slowdown:** A weakened AMOC threatens marine productivity in the North Atlantic, alters weather patterns, and potentially exacerbates drought conditions in regions like the Sahara.
- ❑ **The Indian Ocean Connection:** Research suggests rising Indian Ocean temperatures could bolster AMOC strength, delaying its slowdown, by altering precipitation patterns and saltwater distribution.

Sea Level Rise

- ❑ Recent data from the World Meteorological Organization indicates an acceleration in sea-level rise due to increased ice loss in polar regions.
- ❑ Global mean sea level reached a new high in 2021, rising by an average of 4.5 millimeters per year from 2013 to 2021.
- ❑ This rise, along with more intense tropical cyclones, has led to more frequent extreme events like storm surges and coastal hazards such as flooding and erosion.
- ❑ Certain regions, including the western Tropical Pacific and the South-west Pacific, are experiencing particularly accelerated sea-level rise, according to the IPCC.
- ❑ The IPCC projects that sea levels could rise by an additional 30 to 60 centimetres by the end of the 21st century. This rising sea level is eroding the coast at a higher intensity.
- ❑ **Example:**
  - The city of Jakarta, Indonesia, is sinking at a rate of 10 centimeters per year due to a combination of factors, including groundwater extraction and rising sea levels.
  - Venice, Italy, is also sinking and eroding due to the rise of sea level.

Marine Heatwaves

- ❑ The frequency of marine heatwaves has doubled, with greater intensity and duration, according to the IPCC, attributing human influence as the primary cause of ocean warming since the 1970s.
- ❑ Most heat waves occurred from 2006 to 2015, leading to widespread coral bleaching and reef deterioration. In 2021, nearly 60% of the world's ocean surface experienced at least one marine heatwave.
- ❑ The UN Environment Programme warns that all coral reefs worldwide could bleach by the century's end if ocean temperatures continue to rise.
- ❑ Coral bleaching results from stress-induced loss of microscopic algae crucial for reef survival. The last global bleaching event, spanning 2014 to 2017, affected reefs across the Pacific, Indian, and Atlantic oceans.

Loss of Marine Biodiversity

- Elevated temperatures heighten the risk of irretrievable harm to marine and coastal ecosystems.
- Presently, extensive transformations are evident, including the degradation of vital coral reefs and mangroves supporting ocean life, and the migration of species to cooler waters at higher latitudes.
- Recent estimates by UNESCO suggest that over half of the world's marine species could face extinction by 2100. With the current temperature rise of 1.1°C, an estimated 60% of marine ecosystems have already undergone degradation or are being unsustainably exploited.
- If the global average temperature rises by 1.5°C, then it is estimated that 70-90% of the corals would vanish, whereas if the rise is by 2°C, then 99% of corals may disappear.

Coastal Erosion

- Rising sea levels lead to increased Coastal Erosion, inundation of low-lying areas, and the loss of coastal habitats.
- Rising sea levels and more frequent and severe storms are eroding coastlines, destroying homes and businesses, and threatening ecosystems.
- Coastal erosion is expected to displace an estimated 140 to 300 million people worldwide by the end of the 21st century.
  - **Example:** The coast of Alaska is eroding at a rate of up to 3 metres per year in some areas.

Increased Intensity of Hazards

- Climate change contributes to stronger and more frequent storms, causing severe damage to coastal infrastructure.
- The IPCC 6th AR found that climate change is making tropical storms and hurricanes more intense. This is because warmer sea surface temperatures provide more energy for developing storms.
- The report found that the proportion of Category 4 and 5 hurricanes is projected to increase and that the maximum wind speeds of hurricanes are also projected to increase. This is increasing coastal flooding frequency, intensity, duration and range.
- The report also found that climate change is making hurricanes more likely to stall or move slowly, which can lead to more flooding and damage.

Ocean Acidification

(Dealt in detail in the later half of the chapter)

Altered Coastal Climate Patterns

- The IPCC 6th AR found that global average temperatures have increased by about 1.1°C since the pre-industrial era, and that coastal regions are warming at a faster rate than inland areas. This is due to the fact that coastal areas are exposed to both the warming air and the warming ocean.
- The report also found that the frequency and intensity of extreme weather events, such as heat waves, storms, and floods, are increasing in coastal regions.

Case Study of Impact of Climate Change in Coastal Regions - KIRIBATI

- A 2022 UNESCO report highlights Kiribati's existential threat from rising sea levels due to climate change. Since the 1950s, the nation has experienced a 20-centimeter rise in average sea levels, with ongoing projections.
- This increase is causing erosion, inundation of low-lying areas, and saltwater intrusion into freshwater sources. These impacts jeopardize Kiribati's livelihoods, prompting considerations of relocation to higher ground.

Socio Economic Impact

- **Displacement and Relocation:** Rising sea levels and extreme weather events compel coastal communities to relocate, posing social and economic hurdles.
  - The IPCC's 6th AR has introduced a new high-end risk scenario, stating that a global rise "approaching 2 m by 2100 and 5 m by 2150 under a very high greenhouse gas emissions scenario cannot be ruled out due to deep uncertainty in ice sheet processes."
  - The World Bank anticipates 216 million people in six regions could move within their countries by 2050, while the UN Refugee Agency notes 20 million already displaced by climate change.

Case Study: Tuvalu

- **Tuvalu:** Tuvalu is a small island nation in the Pacific Ocean that is at risk of being submerged by rising sea levels. The government of Tuvalu has purchased land in New Zealand to relocate its citizens.

- **Infrastructure Damage and Loss of Livelihoods:** The IPCC's 6th AR highlights climate change as a major threat to coastal cities and infrastructure, citing sea level rise, storm surges, and extreme weather events as causes of damage.
  - A case study by the WEF on New York City reveals increasing flood risk, with Superstorm Sandy inflicting $60 billion in damages. If trends persist, NYC could face an annual average of $95 billion in flood-related damage by century's end.
- **Saltwater Intrusion:** The IPCC's 6th AR highlights saltwater intrusion as a rising issue in coastal regions globally, attributing it to sea level rise and extreme weather events.
  - A UNESCO case study on the Mekong Delta in Vietnam illustrates the impact, with saltwater intrusion affecting agriculture and aquaculture, posing challenges for local livelihoods.

- **Tourism Decline:** UNESCO has identified over 500 coastal World Heritage Sites, many facing climate change threats. The World Bank predicts up to a 10% revenue loss in global tourism by 2050 due to climate change.
  - IPCC AR6 highlights coastal tourism's vulnerability to sea level rise, extreme weather, ocean acidification, and coral bleaching. Sea level rise could displace millions and damage tourism infrastructure. Extreme events like cyclones pose further risks.

Desert Region

- Arid and desert areas are particularly sensitive to climate change due to their unique environmental conditions and limited water resources. The AR6 report underscores several key challenges
- **Rising temperatures:** Arid regions are experiencing a faster rate of warming compared to the global average. This increase in temperature intensifies evaporation, leading to reduced soil moisture and exacerbating drought conditions.
  - Arid regions are warming at a rate twice the global average. Evaporation rates in arid regions have increased by 10% in the past 50 years.
  - Soil moisture in arid regions has declined by 20% in the past 50 years.
  - The frequency and intensity of droughts in arid regions have increased by 50% in the past 50 years.
- **Shifting precipitation patterns:** Precipitation patterns in arid areas are becoming more erratic and unpredictable. This variability in rainfall makes it difficult to manage water resources and sustain agriculture.
  - The IPCC AR6 predicts significant precipitation changes in desert regions, driven by factors like atmospheric circulation patterns and land use.
  - Arid areas face rising risks of extreme events: heatwaves, sandstorms, and flash floods. Global Climate Observing System notes a 50% increase in heatwaves since 1980, while WMO cites a 29% rise in droughts since 1900.
  - UNEP observes intensified sandstorms, and the World Bank notes escalating damage from flash floods.
- **Water Resource Challenge:** Glacial melt and declining snowpacks in mountains threaten water supply to arid regions downstream.
  - IPCC AR6 highlights that arid and semiarid areas, hosting over 2.5 billion people, face groundwater depletion.
  - By 2050, water scarcity may impact over 5 billion people globally, with these regions bearing a significant brunt.
- **Land degradation and desertification:** Desertification and land degradation impact around 2 billion hectares globally, notably in drylands housing over 2 billion people.
  - In India, approximately 96.4 million hectares suffer from this issue, affecting states like Rajasthan and Maharashtra severely.
  - Climate change exacerbates these processes, reducing soil fertility and vegetation cover while increasing erosion, particularly in arid regions.
  - The economic cost of land degradation is estimated at $7-10 trillion annually, and up to 135 million people could be displaced by 2050.
  - Agriculture faces significant threats, with up to 10% of global food production lost due to land degradation, and around 50% of pastoral lands degraded.

Aravalli Green Wall Project

An ambitious initiative is underway to establish a green belt buffer spanning 1,400 kilometers in length and 5 kilometers in width around the Aravali Mountain range, encompassing regions across Haryana, Rajasthan, Gujarat, and Delhi. The primary goal of India's Green Wall initiative will be to tackle the increasing incidence of land degradation and the eastward encroachment of the Thar desert.

The endeavor draws inspiration from Africa's 'Great Green Wall' project, initiated in 2007, which extends from Senegal in the West to Djibouti in the East.

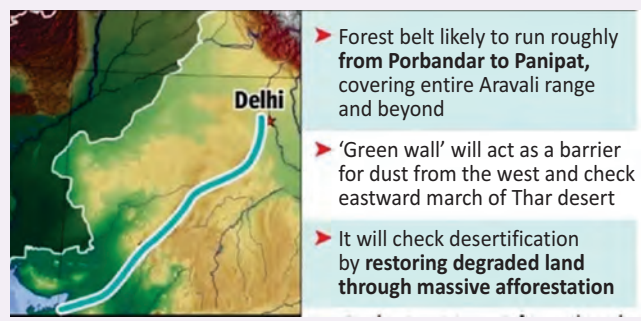

Delhi
Forest belt likely to run roughly **from Porbandar to Panipat,** covering entire Aravali range and beyond
'Green wall' will act as a barrier for dust from the west and check eastward march of Thar desert
It will check desertification by **restoring degraded land through massive afforestation**

Fig. 11.21: Aravali Green Wall Project

Sahel

The Sahel is a region of Africa that is located south of the Sahara Desert. The Sahel has been experiencing a long-term decline in precipitation, which has led to widespread drought and desertification. The IPCC AR6 report found that the decline in precipitation in the Sahel is likely to continue in the future.

Fig. 11.22: The Sahel Region

Great Green Wall of the Sahara and Sahel

The **Great Green Wall** of the Sahara and Sahel Initiative (GGWSSI) aims to combat land degradation in the Sahel region through tree planting and land restoration. Led by the African Union, it seeks to create an 8,000-kilometre strip of vegetation across 11 countries, restore 100 million hectares of land, and generate jobs while sequestering carbon dioxide. Although progress includes restoring over 11 million hectares and benefiting a million people, challenges like climate change, conflicts, and poverty persist. Collaboration among international organizations and ongoing efforts are crucial to achieving the GGWSSI's ambitious goals.

Fig. 11.23: The Great Green Wall Project

Socio-Economic Impact

- **Water Scarcity:** Climate change-induced water scarcity jeopardizes human consumption, agriculture, and livestock, triggering conflicts over resources and community displacement.
- **Water Violence:** Water violence refers to the use of water as a weapon of war or conflict, causing harm to people or property, denying access to water as punishment, or manipulating water resources for political or military advantage.
  - Common forms of water violence include direct attacks on water infrastructure, such as bombing dams, water treatment plants, and irrigation systems, and denying access to water.
  - Water violence can also involve contaminating water sources, such as introducing pollutants into water supplies or allowing agricultural runoff to contaminate water sources.
  - In the 2021 Gaza Conflict, water scarcity has been exacerbated by the conflict between Israel and Hamas. Water violence is a growing problem in Africa, where water resources are increasingly scarce and contested, contributing to conflicts such as coups, civil wars, and terrorism.
  - Lack of water leads to a cycle of poverty, violence, and unrealized human capital, with some leaving as climate refugees and others staying to gain power through coups, ethnic conflicts, or joining terrorist outfits.
- **Food insecurity:**
  - **Population Growth and Poverty:** Rising temperatures and erratic rainfall patterns worsen food insecurity in arid regions. Population growth and poverty exacerbate this vulnerability.
  - **IPCC Projection:** IPCC's 6th AR predicts a 20% to 50% increase in food insecurity in drylands by the century's end. Climate change amplifies existing drivers like land degradation and water scarcity.
  - **Horn of Africa:** Crop yields in the Horn of Africa have declined by up to 20% due to climate change, leading to widespread food insecurity affecting millions.
- **Livelihood loss, Displacement, and migration:** Climate change disrupts traditional livelihoods in arid regions, leading to displacement and migration. The FAO estimates up to 140 million displaced by 2050, with arid areas heavily affected.
  - The World Bank projects 216 million internal migrants by 2050, with arid regions significant sources of displacement.

Cryosphere

The cryosphere refers to the frozen components of Earth's surface, including ice caps, glaciers, snow cover, permafrost, and sea ice. Climate change poses significant threats to the cryosphere, leading to accelerated melting, rising sea levels, and potential disruptions to ecosystems and human activities in polar and mountainous regions.

- **Global Warming:** Global warming melts glaciers and polar ice caps, raising sea levels and altering climate patterns. For instance, the Greenland Ice Sheet's rapid ice loss injects freshwater into the North Atlantic, affecting ocean circulation and regional climates.
- **Invasive Alien Species:** As ice melts in the Arctic and Antarctic, invasive species exploit new routes into once-isolated ecosystems. For instance, warming in the Antarctic facilitates invaders like the king crab, endangering native species like Antarctic krill vital to the Southern Ocean's food web.
- **Pollution:** Pollution, like microplastics and persistent organic pollutants, accumulates in polar ice and snow. As these icy reserves melt, they release pollutants, endangering Arctic wildlife. For instance, microplastics found in Arctic sea ice and snow pose risks to animals like polar bears, while banned substances like DDT and PCBs can harm Arctic ecosystems when reintroduced.
- **Resource Extraction:** Thawing permafrost in the Arctic enables easier extraction of natural resources like oil and gas. Yet, this poses environmental risks. For instance, in Siberia, Russia, expanded oil and gas activities due to permafrost thawing can cause oil spills and disrupt habitats, impacting local ecosystems and endangered species like the Siberian crane.

- **Whaling:** Melting ice alters whale distribution and behavior, exposing them to increased risk from whaling. For instance, in the Arctic, receding ice may allow commercial whaling to target previously protected whale populations, endangering species like the bowhead whale and disrupting marine.
- **Geopolitical Competition:** The melting of Arctic sea ice has sparked geopolitical competition as nations vie for control over resources and territories. For example, Russia, the United States, and Canada are asserting claims and pursuing resource exploitation in the region, symbolized by Russia's symbolic flag planting on the North seabed.

IGNITE YOUR MIND

Melting Point Mystery: Shrinking Ice Giants

Earth's giant ice cubes – glaciers and polar ice caps – are shrinking at an alarming rate. What role do these frozen giants play in our climate system, and how is their decline impacting us?

Arctic Amplification

Arctic amplification refers to the phenomenon where changes in the Earth's atmosphere result in a greater temperature difference near the poles compared to the rest of the world. This amplification is assessed concerning the planet's average temperature change and is particularly pronounced in the northern latitudes, known as Arctic amplification.

Causes of Arctic Amplification

- **Greenhouse Gas Effect:** An increase in greenhouse gases affects the atmosphere's net radiation balance, contributing to Arctic amplification.
- **Ice-Albedo Feedback:** The reflective nature of sea ice and snow (high albedo) allows them to reflect most solar radiation. As sea ice melts, the Arctic Ocean absorbs more solar radiation, amplifying warming.
- **Lapse Rate Feedback:** With warming, the rate at which temperature drops with elevation (lapse rate) decreases, further amplifying Arctic warming.

Consequences of Arctic Warming

- **Thinning of Greenland Ice Sheet:** The rapid melting of the Greenland ice sheet has led to a significant decrease in sea ice accumulation since 2000, resulting in the loss of billions of tons of ice daily.
- **Rise in Sea Level:** The melting Greenland ice sheet is a major contributor to rising sea levels, with potential catastrophic consequences for coastal regions if the entire sheet were to melt.
- **Impact on Biodiversity:** Warming oceans and changing environmental conditions are affecting Arctic biodiversity, leading to disruptions in marine ecosystems and food chains.

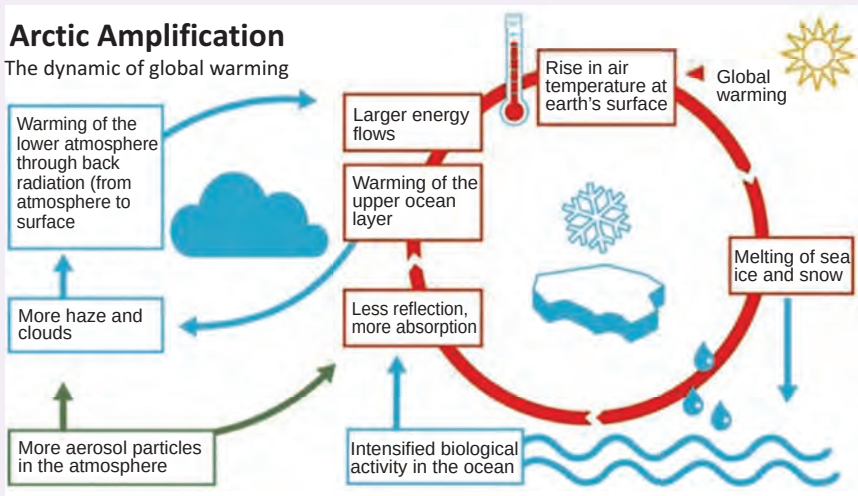

Arctic Amplification
The dynamic of global warming
Warming of the lower atmosphere through back radiation (from atmosphere to surface
More haze and clouds
More aerosol particles in the atmosphere
Larger energy flows
Warming of the upper ocean layer
Less reflection, more absorption
Intensified biological activity in the ocean
Rise in air temperature at earth's surface
Global warming
Melting of sea ice and snow

Fig. 11.24: Arctic Amplification

- **Thawing of Permafrost:** Thawing permafrost releases carbon and methane, potent greenhouse gases, further exacerbating global warming. Additionally, the release of long-dormant bacteria and viruses from permafrost poses health risks.

The Arctic amplification poses significant challenges and risks, not only for the Arctic region but also for global climate stability and biodiversity. Addressing these challenges requires urgent and coordinated efforts to mitigate greenhouse gas emissions and adapt to the changing climate.

Impact on Vulnerable Sections

- Certain demographic groups like women, children, elderly, ethnic and religious minorities, differently abled, poor, small and marginal farmers etc face heightened vulnerability to the effects of climate change due to socioeconomic factors such as income, education, healthcare access, and housing.
- These factors influence their capacity to prepare for and withstand climate-related hazards. Living in areas prone to climate-related health risks, like flooding, extreme heat, and air pollution, exacerbates their susceptibility.
- Additionally, they often contend with higher rates of pre-existing medical conditions, including physical disabilities, mental health issues, kidney disease, diabetes, asthma, or heart disease, which can be exacerbated by climate impacts.
- In urban and rural settings with deteriorating infrastructure, access to resources and care during extreme weather events may be challenging.
- Limited financial resources or cultural and linguistic barriers may further hinder access to healthcare, social services, and nutritious food for individuals in these communities.

Key Threats to the Health of Socially Vulnerable People

- **Heat-related illnesses:** Rising temperatures and more frequent, intense heat waves increase heat-related illness risks, especially among vulnerable urban communities. Limited cooling options due to inadequate housing exacerbate this vulnerability, particularly for socially disadvantaged groups.
- **Respiratory Illnesses:** Climate change can worsen outdoor air pollution, putting socially vulnerable urban populations at higher health risk due to limited access to pollution-reducing measures.
  - These groups are more susceptible to pollutants and face increased risk of severe illnesses and hospitalizations.
  - Climate change also increases allergens, asthma, dust, and wildfire smoke hazards, impacting both urban and rural areas.
  - Damp indoor environments in older or poorly maintained buildings pose additional health risks for low-income households without access to air cleaners.
- **Water-Related Illnesses:** Climate change affects water resources by bringing disease-carrying organisms into drinking and recreational waters through various means like temperature changes and heavier rains.
  - Low-income areas, both urban and rural, face more risks due to aging water infrastructure, which struggles with climate impacts like flooding.
  - Low-income households near floodplains face more exposure to water pollutants and have higher flood insurance costs and accessibility challenges.
- **Food system impacts:** Climate-related hazards like floods, wildfires, and droughts may disrupt food production and distribution, affecting food quality and availability.
  - This can exacerbate challenges for communities of color(western nations) and low-income populations already facing difficulties accessing nutritious food due to financial constraints and limited access to affordable, high-quality options.

IGNITE YOUR MIND

Airpocalypse: Linking Air Pollution and Climate Change Imagine breathing air that harms your lungs and damages the environment. What is the link between air pollution and climate change, and how can we create a future where we breathe freely?

- **Vector borne diseases:** Warmer temperatures resulting from climate change can lead to increased mosquito development and biting rates globally. Additionally, higher levels of rainfall and rising sea levels can contribute to the proliferation of mosquito breeding sites worldwide.
- **Mental Health Effects:** Extreme weather events and environmental changes can exacerbate existing mental health conditions and create new ones, straining access to care and support systems. Accessibility barriers and limited resources further compound these challenges.

Overlapping Vulnerabilities

Some individuals may belong to multiple vulnerable groups affected by climate change, heightening their health risks.

- For **example,** an **elderly women** person with **limited income** and **mobility challenges** may face difficulties accessing safe locations during **heatwaves.**
- Additionally, certain immigrant communities of color, and low-income individuals may have elevated rates of chronic medical conditions exacerbated by climate change impacts.

Vulnerability Group	Impact	Example
Women	Heightened vulnerability due to societal norms.	Women in rural areas of Africa face increased workloads due to water scarcity.
	Disproportionate impacts due to limited resources.	Women in India's Sundarbans struggle as mangrove loss affects fishing.

Vulnerability Group	Impact	Example
	Risk of violence due to resource scarcity.	Women in post-disaster settings often face increased risks of gender-based violence.
	Crucial role in climate action.	Women-led initiatives in Uganda promote sustainable farming and resource management.
Children	Physically and emotionally vulnerable.	Child malnutrition rises in climate-affected regions due to crop losses.
	Disruption in education due to extreme events.	Cyclone Idai in Mozambique damaged schools and disrupted children's education.
	Long-term consequences of early exposure.	Children affected by climate-related displacement face increased risks of poverty.
Tribal Population	Loss of traditional resources due to ecosystem changes	Indigenous tribes in the Amazon face threats as deforestation destroys habitats.
	Disruption of cultural practices and traditions.	Arctic indigenous communities struggle as melting ice affects hunting and fishing.
	Health risks from climate-related hazards.	Indigenous populations in Alaska experience higher rates of respiratory illness due to wildfires.
	Forced displacement and migration due to rising sea levels.	Communities in the Pacific Islands are considering relocation due to sea level rise.

Changes in Climate in the Indian Region

The effect of climate change has been differently felt in the different regions, varying with geographical and environmental milieu. The changes observed are:

Indian Ocean Warming

- The sea surface temperature (SST) in the tropical Indian Ocean increased by an average of 1°C between 1951 and 2015, surpassing the global average warming of 0.7°C over the same period.
- Additionally, the ocean heat content in the upper 700 meters of the tropical Indian Ocean has shown a consistent upward trend since the 1950s, with a particularly abrupt rise observed in the past two decades from 1998 to 2015.
- Throughout the twenty-first century, both sea surface temperature (SST) and ocean heat content in the tropical Indian Ocean are expected to persistently increase.

Changes in Rainfall

- From 1951 to 2015, summer monsoon precipitation over Indo Gangetic plains and Western Ghats decreased by approximately 6%, particularly over regions like the Indo-Gangetic Plains and the Western Ghats.
- Research indicates that the radiative impact of human-induced aerosols in the Northern Hemisphere has partially counteracted the anticipated precipitation rise from greenhouse gas warming, contributing to this decline.
- Recent trends show more frequent dry spells (27% higher from 1981 to 2011 compared to 1951 to 1980) and intensified wet spells during the summer monsoon.
- The occurrence of localized heavy rainfall events has increased globally due to higher atmospheric moisture content. In central India, the frequency of extreme daily precipitation events surpassing 150 mm per day rose by approximately 75% from 1950 to 2015.

Droughts

- Over the past six to seven decades, the overall decline in seasonal summer monsoon rainfall has heightened the occurrence of droughts across India. From 1951 to 2016, both the frequency and geographic extent of droughts have notably risen.
- Certain regions, including central India, the southwest coast, southern peninsula, and northeastern India, have witnessed more than two droughts per decade on average during this period.
- Moreover, the area affected by drought has expanded by 1.3% per decade over the same timeframe. Climate models suggest a high probability of increased frequency (>2 events per decade), intensity, and spatial coverage of drought conditions in India by the end of the twenty-first century, driven by amplified variability in monsoon precipitation and heightened atmospheric water vapor demand in warmer conditions under certain scenarios.

Sea Level Rise

- Globally, sea levels have risen due to melting continental ice and the expansion of ocean water in response to global warming. In the North Indian Ocean (NIO), sea-level rise was measured at a rate of 1.06–1.75 mm per year from 1874 to 2004, which has since accelerated to 3.3 mm per year over the last 25 years (1993–2017).

- This rate is comparable to the current global mean sea-level rise. By the end of the twenty-first century, steric sea level in the NIO is projected to increase by approximately 300 mm while the corresponding global mean rise is estimated to be approximately 180 mm.

Tropical Cyclones

- Since the mid-twentieth century (1951–2018), there has been a notable decline in the annual frequency of tropical cyclones in the North Indian Ocean (NIO) basin.
- However, there has been a significant increase in the frequency of very severe cyclonic storms (VSCSs) during the post-monsoon season over the last two decades (2000–2018), with an additional event occurring per decade.
- Nevertheless, there is currently no clear indication of anthropogenic warming contributing to these trends. Climate models predict a rise in the intensity of tropical cyclones in the NIO basin throughout the twenty-first century.

Changes in the Himalayas

- From 1951 to 2014, the Hindu Kush Himalayas (HKH) experienced a temperature increase of approximately 1.3°C. During recent decades, various parts of the HKH have witnessed a decline in snowfall and glacier retreat.
- However, the high-elevation Karakoram Himalayas have seen increased winter snowfall, providing some protection against glacier shrinkage.
- Projections indicate that by the end of the twenty-first century, the annual mean surface temperature over the HKH could rise by approximately 5.2°C under the RCP8.5 scenario.
- While there's a projected increase in annual precipitation, there's also a forecasted decrease in snowfall across the HKH region by the end of the twenty-first century, with significant variability among models.

Since the mid-twentieth century, India has observed rising average temperatures, declining monsoon precipitation, increased occurrences of extreme temperature and rainfall events, droughts, rising sea levels, and heightened intensity of severe cyclones, among other changes in the monsoon system. Scientific evidence strongly suggests that human activities have contributed to these regional climate shifts. Human-induced climate change is expected to persist throughout the twenty-first century. To refine future climate forecasts, especially at the regional level, it is crucial to implement strategic measures to enhance understanding of Earth system processes and to further develop observation systems and climate models.

OZONE

Ozone, a natural gas, is an oxygen allotrope composed of three atoms of oxygen bonded together in a non-linear manner, with the chemical symbol O_3. It exists in two layers of the atmosphere.

- Ozone in the troposphere is considered "bad" as it contributes to air pollution and smog formation, which is harmful to human health.
- Conversely, ozone in the stratosphere is deemed "good" because it shields life on Earth by absorbing harmful ultraviolet (UV) rays from the sun.
- The ozone layer is crucial due to the ozone molecule's configuration and chemical properties, which efficiently absorb UV light, acting as a protective barrier.
- This absorption prevents UV radiation from reaching the Earth's surface, reducing the risk of mutations and harm to plant and animal life.
- Excessive UV exposure can lead to skin cancer and harm all living organisms. Therefore, the ozone layer is essential for sustaining life on Earth.

Ozone Depletion

- The balance between ozone formation and destruction has been disrupted by the introduction of various substances into the atmosphere that react with ozone and deplete it.
- Ozone depletion occurs when the rate of ozone destruction surpasses its formation. This leads to a significant reduction in ozone concentration in specific atmospheric regions, hence the term 'Ozone Depletion.'
- Antarctic: A prominent example of ozone depletion is observed over the Antarctic, where the ozone layer has diminished to approximately 50% of its original levels. The recognition of ozone depletion became widespread only in 1985.

Ozone Hole and Discoveries

- **Ozone Hole Formation:** Severe ozone depletion leads to the creation of the "ozone hole," notably observed over Antarctica through satellite images.
- **Discovery of Link (1974):** In 1974, chemists **Mario Molina** and **Frank Sherwood Rowland** identified the connection between **chlorofluorocarbons (CFCs)** and **ozone breakdown** in the **stratosphere.**
- **Antarctic Findings (1985):** In 1985, geophysicist **Joe Farman,** along with meteorologists **Brian G Gardiner** and **Jonathan Shanklin,** reported abnormally low **ozone concentrations** above **Antarctica,** prompting global action.
- **Scientific Validation:** Subsequent laboratory and atmospheric studies confirmed the significance of these findings. The efforts of **Crutzen, Molina,** and **Rowland** were acknowledged with the **Nobel Prize for Chemistry** in 1995.

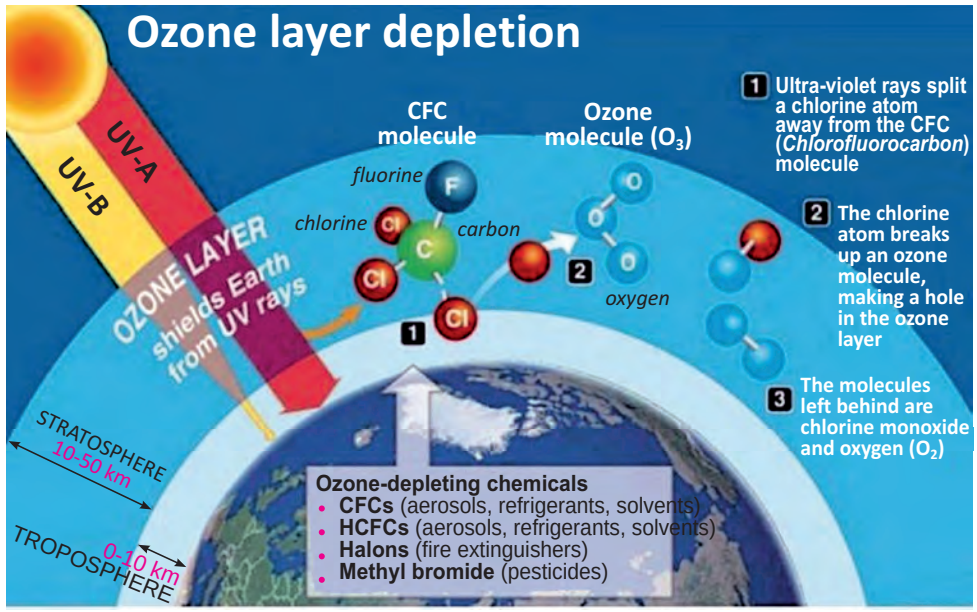

Ozone layer depletion
UV-A
UV-B
OZONE LAYER shields Earth from UV rays
CFC molecule
Ozone molecule (O_3)
fluorine
chlorine
carbon
oxygen
1 Ultra-violet rays split a chlorine atom away from the CFC (Chlorofluorocarbon) molecule
2 The chlorine atom breaks up an ozone molecule, making a hole in the ozone layer
3 The molecules left behind are chlorine monoxide and oxygen (O_2)
STRATOSPHERE 10-50 km
TROPOSPHERE 0-10 km
Ozone-depleting chemicals
CFCs (aerosols, refrigerants, solvents)
HCFCs (aerosols, refrigerants, solvents)
Halons (fire extinguishers)
Methyl bromide (pesticides)

Fig. 11.25: Ozone Layer Depletion

Sources of Ozone Depletion

- Ozone depletion primarily stems from the release of certain human-made chemicals called ozone-depleting substances (ODS). These substances include chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform.
- CFCs were commonly used in refrigerants, solvents, and aerosol propellants, while halons were used in fire extinguishers. When these chemicals are released into the atmosphere, they eventually reach the stratosphere, where they break down ozone molecules through chemical reactions, leading to ozone depletion.
- Additionally, natural processes such as volcanic eruptions can also contribute to ozone depletion by releasing chlorine and bromine-containing gases into the atmosphere.

Mechanism

CFCs

- **Release into Atmosphere:**
  - CFCs are released into the atmosphere through processes like evaporation, for example, from discarded refrigerators.
  - Once in the troposphere, they remain stable due to their thermal properties. In fact, the residence time of CFCs in the atmosphere is estimated to be between 40 and 150 years. During this period, the CFCs move upwards by random diffusion, from the troposphere to the stratosphere.
  - However, when they reach the stratosphere, they are exposed to UV radiation, causing them to break down into chlorine atoms.
- **Chemical Reaction:**
  - This breakdown leads to a chemical reaction where chlorine atoms combine with ozone molecules, forming chlorine monoxide (ClO).
  - Chlorine monoxide then reacts with oxygen atoms to form oxygen molecules (O_2) and regenerate free chlorine atoms (Cl) which again forms chlorine monoxide hence repeating the cycle.
- **Catalytic Process:**
  - Ozone depletion is a catalytic process, where the element responsible for ozone destruction, chlorine, is regenerated at the end of each cycle.
  - A single chlorine atom can destroy thousands of ozone molecules before interacting with reactive nitrogen or hydrogen compounds, which ultimately return chlorine to its reservoirs.

Halons and HBFCs

- **Bromine-containing Compounds:**
  - Halons, HBFCs (hydrobromofluorocarbons), and methyl bromide (a common pesticide) are bromine-containing compounds implicated in ozone depletion.
  - Each bromine atom can destroy hundreds of times more ozone molecules than a chlorine atom.
- **Chemical Reactions:**
  - When bromine combines with ozone, it forms bromine monoxide (BrO) and oxygen (O_2). BrO then reacts with chlorine monoxide (ClO), producing oxygen (O_2) and releasing free bromine (Br) and chlorine (Cl) atoms, which can further deplete ozone.
- **Sulfuric Acid Particles:**
  - Sulfuric acid particles play a role in ozone depletion by releasing chlorine from molecular reservoirs and converting reactive nitrogen into inert forms, thereby preventing the formation of chlorine reservoirs.

❑ **Carbon Tetrachloride:**

- Carbon tetrachloride, a low-cost and highly toxic solvent, and methyl chloroform, used in various consumer products like correction fluid and dry cleaning sprays, are among the aerosols contributing to ozone depletion.

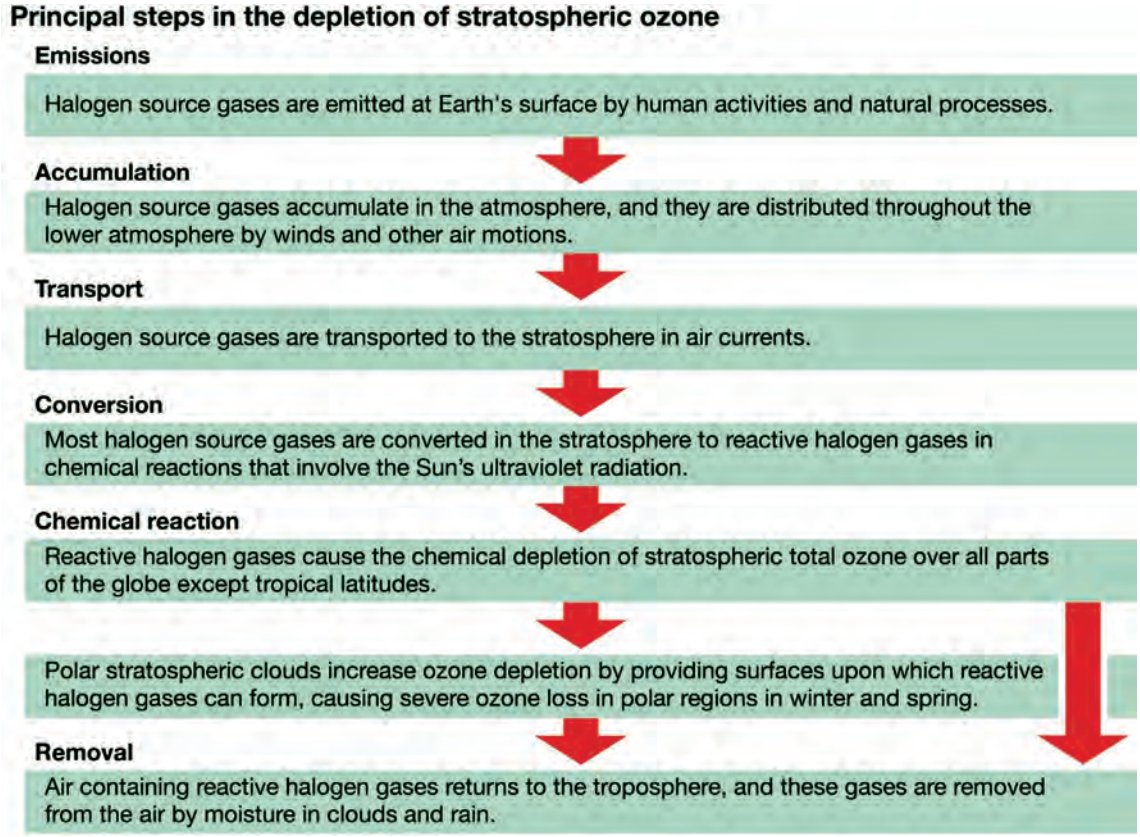

Principal steps in the depletion of stratospheric ozone
Emissions
Halogen source gases are emitted at Earth's surface by human activities and natural processes.
Accumulation
Halogen source gases accumulate in the atmosphere, and they are distributed throughout the lower atmosphere by winds and other air motions.
Transport
Halogen source gases are transported to the stratosphere in air currents.
Conversion
Most halogen source gases are converted in the stratosphere to reactive halogen gases in chemical reactions that involve the Sun's ultraviolet radiation.
Chemical reaction
Reactive halogen gases cause the chemical depletion of stratospheric total ozone over all parts of the globe except tropical latitudes.
Polar stratospheric clouds increase ozone depletion by providing surfaces upon which reactive halogen gases can form, causing severe ozone loss in polar regions in winter and spring.
Removal
Air containing reactive halogen gases returns to the troposphere, and these gases are removed from the air by moisture in clouds and rain.

Fig. 11.26: Principal steps in the depletion of Stratospheric Ozone

Polar Stratospheric Clouds

❑ There are three types of stratospheric clouds:

- Nacreous clouds, also known as "mother-of-pearl" clouds, span lengths of 10 to 100 kilometers and extend several kilometers in thickness, exhibiting a sea-shell-like iridescence.
- The second type of clouds contain nitric acid instead of pure water.
- The third type of clouds share the same chemical composition as nacreous clouds but form at a slower rate, resulting in larger clouds without iridescence.

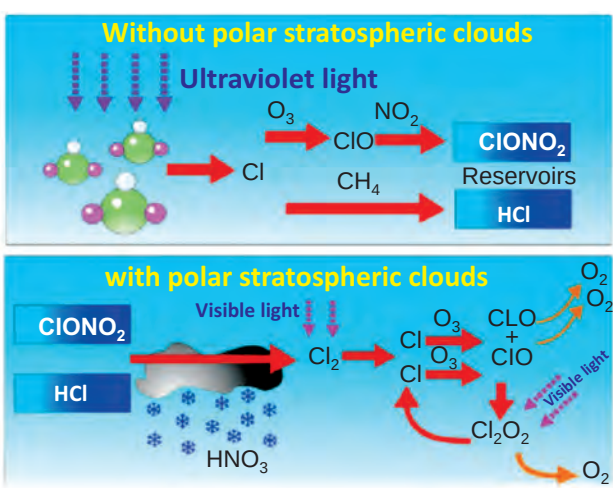


Fig. 11.27: Impact of Stratospheric clouds

❑ The chlorine released from the breakdown of CFCs initially exists as pure chlorine or chlorine monoxide (active chlorine), but these forms react further to produce stable compounds such as chlorine nitrate and HCl, rendering the chlorine inactive.

❑ Chlorine Activation:

- The stable compounds HCl and $ClONO_2$ serve as reservoirs of chlorine, meaning that in order for chlorine to participate in any reactions, it must first be released.
- Polar stratospheric clouds (PSCs) accelerate the release of chlorine from stable compounds like HCl and $ClONO_2$, aiding ozone depletion.

Why is Ozone depletion predominant at the Antarctic?

❑ The Antarctic stratosphere is much colder, enabling Polar Stratospheric Clouds (PSCs) formation below 20 km.

❑ Ozone absorbs sunlight, leading to increased temperature with altitude (in the stratosphere), but depletion of ozone causes cooling, facilitating PSC formation and stabilizing the vortex—a ring of rapidly circulating air confining ozone depletion.

- Unlike the Arctic vortex, which disintegrates by polar spring, the Antarctic vortex persists throughout the polar winter into mid-spring, explaining less prevalent phenomena in the Arctic.
- **In winter months:** June sees the onset of the Antarctic winter and PSC formation; July and August witness PSCs reacting to release chlorine; September sees sunlight return, causing PSC disappearance; October marks the lowest ozone levels; and in November, the vortex breaks down, allowing ozone-rich air from mid-latitudes to replenish the Antarctic stratosphere while ozone-poor air spreads over the southern hemisphere.

IGNITE YOUR MIND

The Ozone Hole: A Hole in the Shield

A thinning layer in the atmosphere allows harmful ultraviolet radiation to reach Earth's surface. What is ozone depletion, and how does it impact human health and ecosystems?

Depletion in The Arctic

Ozone depletion in the Arctic has become more pronounced in recent years.

- The severe depletion experienced over Britain in March 1996 marked the largest ever observed in the northern hemisphere.
- Scientists attribute this to a significant cooling of the upper atmosphere in northern latitudes. Depletion has been steadily increasing since the winter of 1992.
- The primary cause, aside from the accumulation of ozone-depleting chemicals, is the rising cold temperatures in the Arctic stratosphere, which facilitate the formation of Polar Stratospheric Clouds (PSCs).

Measurement of Ozone

Ozone is primarily measured using ground-based instruments like Dobson spectrophotometers, which analyze sunlight absorption by ozone.

- Satellite-based instruments, such as the Total Ozone Mapping Spectrometer (TOMS) and the Ozone Monitoring Instrument (OMI), provide global coverage and measure ozone concentrations in different layers of the atmosphere.
- Balloon-borne ozonesondes directly sample ozone levels in the atmosphere's vertical profile.
- Additionally, ground-level ozone is measured using surface monitors equipped with UV photometers or ozone analyzers.
- **One Dobson Unit (DU)** represents a layer of ozone that would be **0.01 millimeters** thick under standard temperature and pressure conditions.

Environmental Effects of Ozone Depletion

The reduction in total-column ozone leads to increased penetration of solar UV-B radiation (290-315 nm) to the earth's surface, impacting various aspects of the environment.

- **Effects on Human and Animal Health:** Increased risks of eye diseases, skin cancer, and infectious diseases. UV radiation can damage the cornea and lens of the eye, decrease immune response, and contribute to skin cancer development.
- **Effects on Terrestrial Plants:** UV-B radiation affects plant physiological and developmental processes. Different plant species and cultivars respond variably to UV-B, necessitating the use of UV-B tolerant cultivars in agriculture. Changes in species composition may occur in forests and grasslands, affecting biodiversity.

CDOM : Coloured or Chromophoric Dissolved Organic Matter is the part of organic matter that absorbs light in the blue and UV part of the electromagnetic spectrum, staining water a "tea-like" yellow-brown.

- **Effects on Aquatic Ecosystems:** UV-B radiation affects phytoplankton orientation and motility, reducing survival rates. Early developmental stages of aquatic animals can be damaged by UV-B, leading to decreased reproductive capacity and impaired larval development.
- **Effects on Biogeochemical Cycles:** Solar UV radiation impacts terrestrial and aquatic biogeochemical cycles, altering sources and sinks of greenhouse gases. Changes in atmospheric concentrations of key trace gases may affect atmospheric chemistry and climate.
- **Effects on Air Quality:** Reduction in stratospheric ozone increases UV-B radiation in the lower atmosphere, affecting the photo dissociation rates of key trace gases.
  - Increased tropospheric reactivity may lead to higher production of ozone and related oxidants, affecting human health and terrestrial plants.
  - Changes in atmospheric concentrations of hydroxyl radicals may impact the atmospheric lifetimes of climatically important gases.
- **Effects on Materials:** Solar UV radiation adversely affects synthetic and natural polymers, as well as other commercial materials. Increased UV-B content due to ozone depletion accelerates the degradation of materials exposed to sunlight, limiting their outdoor lifespan.

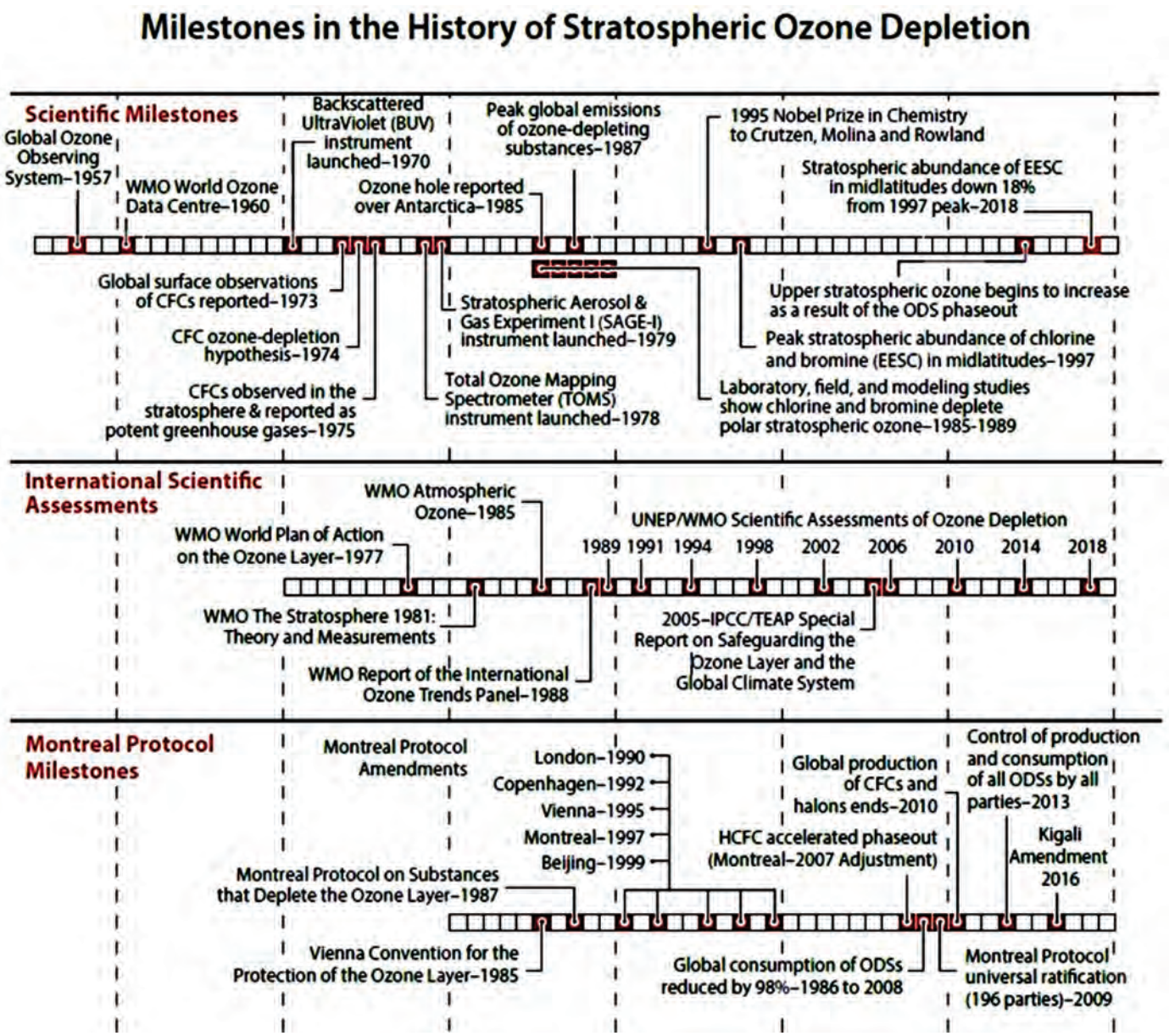

Milestones in the History of Stratospheric Ozone Depletion
Scientific Milestones
Global Ozone Observing System–1957
WMO World Ozone Data Centre–1960
Backscattered UltraViolet (BUV) instrument launched–1970
Ozone hole reported over Antarctica–1985
Peak global emissions of ozone-depleting substances–1987
1995 Nobel Prize in Chemistry to Crutzen, Molina and Rowland
Stratospheric abundance of EESC in midlatitudes down 18% from 1997 peak–2018
Global surface observations of CFCs reported–1973
CFC ozone-depletion hypothesis–1974
CFCs observed in the stratosphere & reported as potent greenhouse gases–1975
Stratospheric Aerosol & Gas Experiment I (SAGE-I) instrument launched–1979
Total Ozone Mapping Spectrometer (TOMS) instrument launched–1978
Upper stratospheric ozone begins to increase as a result of the ODS phaseout
Peak stratospheric abundance of chlorine and bromine (EESC) in midlatitudes–1997
Laboratory, field, and modeling studies show chlorine and bromine deplete polar stratospheric ozone–1985-1989
International Scientific Assessments
WMO Atmospheric Ozone–1985
WMO World Plan of Action on the Ozone Layer–1977
UNEP/WMO Scientific Assessments of Ozone Depletion
1989 1991 1994 1998 2002 2006 2010 2014 2018
WMO The Stratosphere 1981: Theory and Measurements
WMO Report of the International Ozone Trends Panel–1988
2005–IPCC/TEAP Special Report on Safeguarding the Ozone Layer and the Global Climate System
Montreal Protocol Milestones
Montreal Protocol Amendments
London–1990
Copenhagen–1992
Vienna–1995
Montreal–1997
Beijing–1999
Global production of CFCs and halons ends–2010
HCFC accelerated phaseout (Montreal–2007 Adjustment)
Control of production and consumption of all ODSs by all parties–2013
Kigali Amendment 2016
Montreal Protocol on Substances that Deplete the Ozone Layer–1987
Vienna Convention for the Protection of the Ozone Layer–1985
Global consumption of ODSs reduced by 98%–1986 to 2008
Montreal Protocol universal ratification (196 parties)–2009

Fig. 11.28: Some Milestones In Ozone Depletion

Ozone Protection

Global Efforts

In the late 1980s, world governments united to safeguard the Earth's ozone layer by eliminating ozone-depleting substances produced by human activities through the following actions:

Vienna Convention (1985)

- The Vienna Convention, established in 1985, laid the groundwork for protecting the ozone layer and is often referred to as a framework convention. It provided a framework for international efforts to address ozone depletion.
- Unlike the Montreal Protocol, the Vienna Convention did not mandate specific actions for countries to control ozone-depleting substances.
- Instead, it facilitated the agreement on the Montreal Protocol on Substances that deplete the Ozone Layer, which aimed to advance the shared goal of ozone protection.

The Montreal Protocol

- Established in 1987, the Montreal Protocol aimed to address ozone layer depletion. It stands as the first international treaty signed by all nations worldwide and is hailed as a monumental environmental achievement in UN history.
- The primary objective of the Montreal Protocol is to reduce the production and consumption of ozone-depleting substances, thereby safeguarding the ozone layer.
- Under the original agreement, developed nations were mandated to initiate the phase-out of CFCs in 1993, aiming for a 20% reduction from 1986 consumption levels by 1994 and a 50% reduction by 1998.

- Furthermore, developed nations were required to halt the production and consumption of halons at 1986 levels.
- Moreover, amendments to the Montreal Protocol empower the regulation of new chemicals and establish a financial mechanism to assist developing countries in compliance efforts.
- The Montreal Protocol regulates substances categorized in Annexes A (CFCs, halons), B (other fully halogenated CFCs, carbon tetrachloride, methyl chloroform), C (HCFCs), E (methyl bromide), and F (HFCs).

Amendments to the Montreal Protocol

- The London Amendment (1990) revised the schedule for ozone-depleting substances (ODS) phaseout, requiring developed countries to eliminate CFCs, halons, and carbon tetrachloride by 2000, and developing countries by 2010. Methyl chloroform was also added to the controlled substances list, with phased elimination set for 2005 in developed countries and 2015 in developing countries.
- The Copenhagen Amendment (1992) accelerated the phaseout of ODSs and introduced a phaseout of hydrochlorofluorocarbons (HCFCs) in developed nations, starting in 2004. CFCs, halons, carbon tetrachloride, and methyl chloroform were targeted for complete elimination by 1996 in developed countries. Additionally, methyl bromide consumption was capped at 1991 levels.

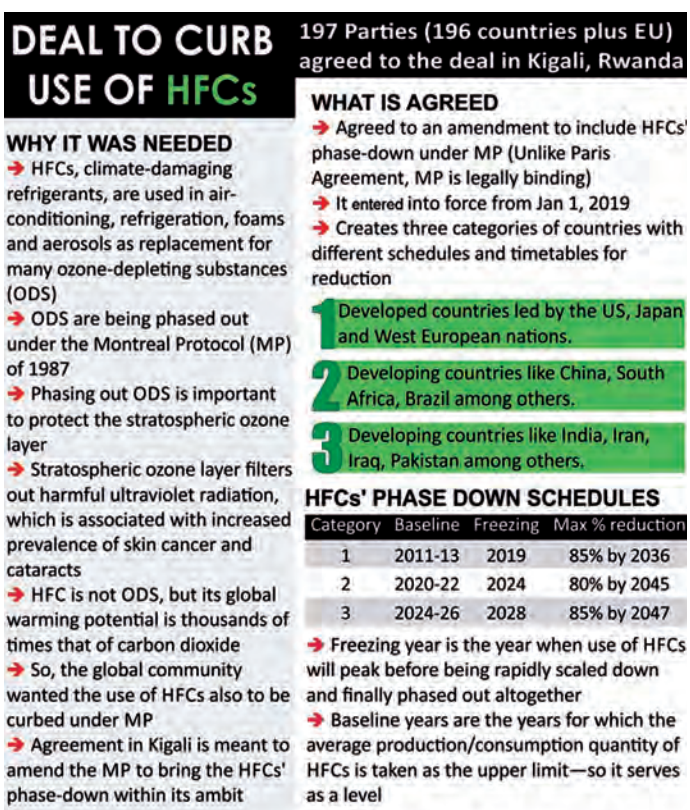

DEAL TO CURB USE OF HFCs
197 Parties (196 countries plus EU) agreed to the deal in Kigali, Rwanda
WHY IT WAS NEEDED
HFCs, climate-damaging refrigerants, are used in air-conditioning, refrigeration, foams and aerosols as replacement for many ozone-depleting substances (ODS)
ODS are being phased out under the Montreal Protocol (MP) of 1987
Phasing out ODS is important to protect the stratospheric ozone layer
Stratospheric ozone layer filters out harmful ultraviolet radiation, which is associated with increased prevalence of skin cancer and cataracts
HFC is not ODS, but its global warming potential is thousands of times that of carbon dioxide
So, the global community wanted the use of HFCs also to be curbed under MP
Agreement in Kigali is meant to amend the MP to bring the HFCs' phase-down within its ambit
WHAT IS AGREED
Agreed to an amendment to include HFCs' phase-down under MP (Unlike Paris Agreement, MP is legally binding)
It entered into force from Jan 1, 2019
Creates three categories of countries with different schedules and timetables for reduction
1 Developed countries led by the US, Japan and West European nations.
2 Developing countries like China, South Africa, Brazil among others.
3 Developing countries like India, Iran, Iraq, Pakistan among others.
HFCs' PHASE DOWN SCHEDULES
Category Baseline Freezing Max % reduction
1 2011-13 2019 85% by 2036
2 2020-22 2024 80% by 2045
3 2024-26 2028 85% by 2047
Freezing year is the year when use of HFCs will peak before being rapidly scaled down and finally phased out altogether
Baseline years are the years for which the average production/consumption quantity of HFCs is taken as the upper limit—so it serves as a level

Fig. 11.29: Kigali Amendment

- The Montreal Amendment (1997) expanded the phaseout to include HCFCs in developing countries and methyl bromide in both developed and developing countries, with elimination deadlines set for 2005 and 2015, respectively.
- The Beijing Amendment (1999) introduced stricter controls on HCFC production and trade. Bromochloromethane was also added to the controlled substances list, with a phaseout deadline of 2004.
- The Kigali Amendment (2016) extended regulations to reduce the production and use of hydrofluorocarbons (HFCs), as these substances, though less harmful to the ozone layer, contribute significantly to climate change as potent greenhouse gases. Industries had adopted HFCs as alternatives to ozone-depleting substances, but their environmental impact on climate prompted their regulation.

India's Initiatives

- The Government of India has delegated responsibility for ozone layer protection and the implementation of the Montreal Protocol to the Ministry of Environment, Forest and Climate Change (MoEF&CC).
- MoEF&CC has established an Empowered Steering Committee (ESC), chaired by the Secretary (EF&CC), along with two standing committees: the Technology and Finance Standing Committee (TFSC) and the Standing Committee on Monitoring.
- The ESC oversees the implementation of Montreal Protocol provisions, policy review, project approvals, and monitoring.
- An Ozone Cell, serving as the National Ozone Unit (NOU), has been set up by the Ministry to ensure effective implementation of the Montreal Protocol and India's ODS phase-out program.
- India formulated a comprehensive Country Program (CP) in 1993 for ODS phase-out, aligning with its National Industrial Development Strategy and accessing funds from the Montreal Protocol's financial mechanism.
- India has phased out the production and consumption of CFCs, except for their use in Metered Dose Inhalers (MDIs) for asthma and COPD treatment, which ceased in December 2012.
- Halons were completely phased out in India by January 1, 2010.
- The Ozone Cell is currently focused on phasing out Hydrochlorofluorocarbons (HCFCs) according to the accelerated schedule set by the Montreal Protocol.
- India has implemented various projects in collaboration with implementing agencies and stakeholders, including the Accelerated CFC Production Sector Phase-out Project, National CTC Phase-out Plan, and HCFC Phase-out Management Plan (HPMP) stages I and II.
- HCFC-141b, a significant contributor to ozone-depleting chemical consumption in India's foam sector, was successfully phased out in 2020, marking a milestone in India's efforts towards ozone protection.

India Surpasses Montreal Protocol Targets

- India has successfully eliminated the ozone-depleting and climate-warming chemical HCFC 141b ahead of schedule, as reported jointly by the Environment Ministry and UNDP during a side-event of the annual climate talks COP28.
- Achieving a remarkable **33 percent reduction in emission intensity of the economy in 2019**, **India has exceeded its 2030 target**. India Surpasses Montreal Protocol Targets
- India has successfully eliminated the ozone-depleting and climate-warming chemical HCFC 141b ahead of schedule, as reported jointly by the Environment Ministry and UNDP during a side-event of the annual climate talks COP28.
- Achieving a remarkable **33 percent reduction in emission intensity of the economy in 2019**, **India has exceeded its 2030 target**.
- The issuance of the Ozone Depleting Substances (Regulation and Control) Amendment Rules, 2019 under the Environment (Protection) Act, 1986, prohibits the import of HCFC-141b, marking the complete phasing out of this significant ozone-depleting chemical.
- **HCFC-141b**, primarily used by foam manufacturing enterprises as a blowing agent in rigid polyurethane (PU) foam production, is one of the most potent ozone-depleting chemicals after Chlorofluorocarbons (CFCs).
- **Achievements in Implementing the Montreal Protocol:** India, a party to the Montreal Protocol since 1992, has made significant strides in implementing measures to phase out Ozone-Depleting Substances (ODS).
  - By January 1, 2010, India successfully eliminated Chlorofluorocarbons, Carbon Tetrachloride, Halons, Methyl Bromide, and Methyl Chloroform.
  - Presently, the phased reduction of Hydrochlorofluorocarbons (HCFCs) is underway in stages: Stage I from 2012 to 2016 (completed), Stage II from 2017 to 2023 (ongoing), and Stage III from 2023 to 2030 (upcoming).
  - Phase out of HCFCs in manufacturing of new equipment must be completed by 31.12.2024 and complete phase out of HCFCs as on 1.1.2030 for all controlled applications.
  - These efforts are estimated to result in a reduction of greenhouse gas (GHG) emissions, with projections indicating a decrease of 465 million tonnes CO_2 equivalent by 2022 and 778 million tonnes CO_2 equivalent by 2030.

Ozone Layer Recovery

- Since the implementation of the Montreal Protocol, global consumption of ozone-depleting substances **(ODS)** has plummeted by approximately 98%.
- Consequently, the atmospheric concentration of the most harmful ozone-depleting substances is declining, and the ozone layer is displaying initial signs of recovery.
- In the early 2000s, scientists anticipated a gradual increase in stratospheric ozone levels over the following decades.
- However, the Antarctic ozone hole reached its maximum size in 2000, spanning 29.9 million square km (11.5 million square miles), but had reduced to 24.8 million square km (9.6 million square miles) by 2021.
- A 2018 United Nations report predicted a gradual closure of the Antarctic ozone hole, with stratospheric ozone concentrations returning to 1980 levels by the 2060s.
- In the Arctic region, ozone levels are projected to return to 1980 values by the mid-2030s.

ACID RAIN

Acid rain is a form of precipitation that contains acidic components, such as sulfuric acid (H_2SO_4) and nitric acid (HNO_3), resulting in a pH level below 5.6. It forms when emissions of sulfur dioxide (SO_2) and nitrogen oxides (NOx) interact with water vapor and other atmospheric components to create sulfuric and nitric acids. These acids then fall to the earth's surface as rain, snow, fog, or even dry particles. Acid rain can have significant environmental, economic, and social impacts, prompting the need for mitigation measures.

Taj Mahal and Statue of Liberty

- Acid rain reacts with the marble surface of the Taj Mahal, which is primarily composed of calcium carbonate, causing degradation and discoloration.

  $CaCO_3(s) + H_2SO_4(l) \rightarrow CaSO_4(s) + H_2O(l) + CO_2(g)$
- Over the past 30 years, the Statue of Liberty, constructed primarily of copper, has undergone damage due to the combined effects of acid rain and oxidation, resulting in a greenish hue.

IGNITE YOUR MIND

Acid Rain Riddle:

Environmental Threat Imagine rain that damages buildings, forests, and harms aquatic life. What causes this acidic rain, and how are human activities linked to this environmental threat?

OCEAN ACIDIFICATION (THE "EVIL TWIN" OF GLOBAL WARMING)

- Oceans play a crucial role as a CO_2 reservoir, absorbing approximately one-third of the CO_2 generated by human activities and serving as a buffer against climate change.
- Ocean acidification refers to the alteration in ocean chemistry, characterized by a decrease in ocean pH (indicating an increase in hydrogen ion concentration), primarily caused by the absorption of carbon compounds from the atmosphere by the ocean.

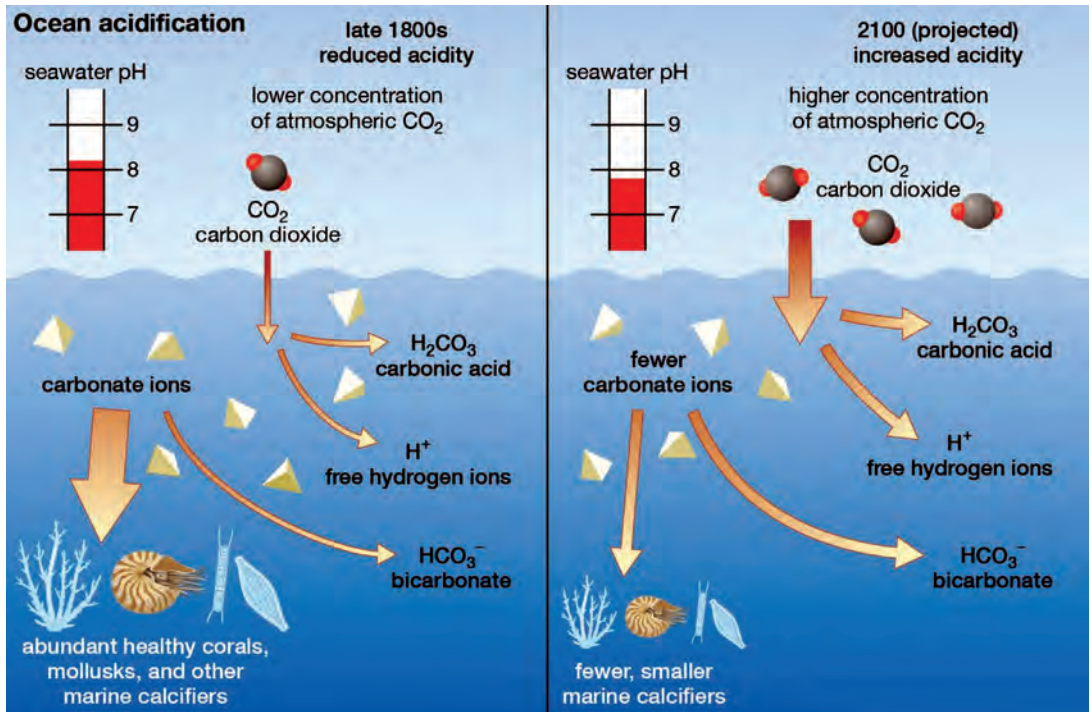


Fig. 11.30: Ocean Acidification

- As the ocean absorbs more atmospheric carbon dioxide, the concentration of hydrogen ions in the ocean rises, leading to a decline in carbonate ion concentration, a decrease in ocean pH, and a reduction in ocean alkalinity. This phenomenon is termed ocean acidification.

Effect of CO_2 on Ocean Acidification

- The uptake of atmospheric carbon dioxide is surpassing the ocean's natural buffering capacity, leading to ocean acidification.
- Since the industrial revolution, the pH of surface ocean waters has decreased by approximately 0.1 pH unit, corresponding to a 30% increase in ocean hydrogen ion concentration.
- Despite the ocean's current alkaline state with a pH around 8.0, the term "ocean acidification" is used to denote the trend of decreasing pH, irrespective of the starting pH level.
- In essence, "acidification" describes the overall direction of pH change, regardless of the initial pH level.

Influence of other factors: Other factors can locally influence the chemical reactions of CO_2 with seawater, exacerbating the effects of ocean acidification. For instance:

- **Acid rain:** Acid rain, with a pH ranging from 1 to 6, can significantly impact surface ocean chemistry. While its effects on ocean acidification are profound at local and regional scales, they remain relatively small on a global scale.
- Eutrophication: Coastal waters are susceptible to excess nutrient inputs, primarily nitrogen, stemming from agricultural runoff, fertilizer use, and sewage discharge. This phenomenon, known as eutrophication, triggers extensive plankton blooms. When these blooms collapse and sink to the seafloor, bacterial decomposition results in decreased seawater oxygen levels and an increase in CO_2, leading to a decline in pH.

Mechanism

- Two reactions play a crucial role in this process.
  - **Firstly,** carbon dioxide reacts with water to form carbonic acid, resulting in the release of hydrogen ions. This reaction increases acidity, thereby reducing the pH level.
  - **Secondly,** carbonate ions, CO_2, and water react to produce bicarbonate ions. The combined impact of these reactions not only elevates acidity but also diminishes the availability of carbonate ions.

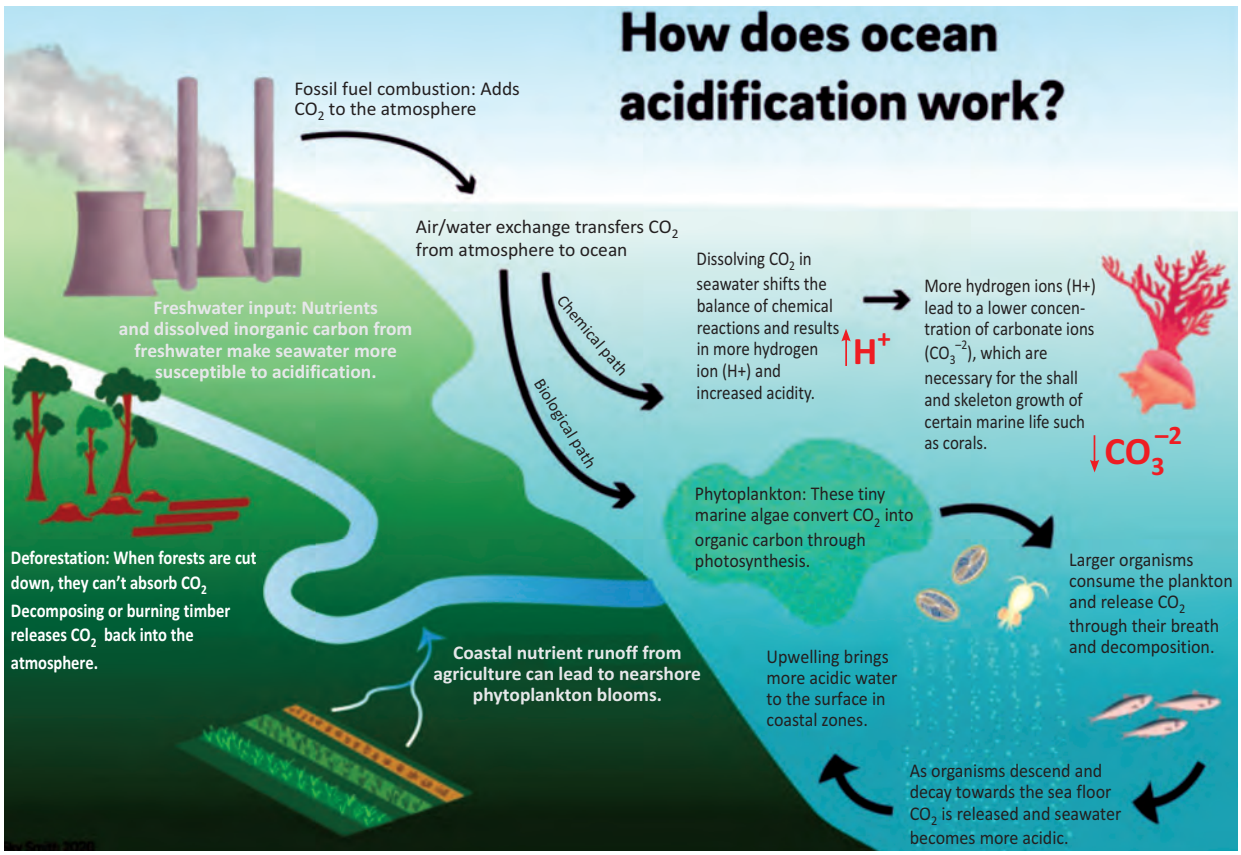

How does ocean acidification work?
Fossil fuel combustion: Adds CO_2 to the atmosphere
Air/water exchange transfers CO_2 from atmosphere to ocean
Freshwater input: Nutrients and dissolved inorganic carbon from freshwater make seawater more susceptible to acidification.
Chemical path
Biological path
Dissolving CO_2 in seawater shifts the balance of chemical reactions and results in more hydrogen ion (H+) and increased acidity.
H^+
More hydrogen ions (H+) lead to a lower concentration of carbonate ions (CO_3^{-2}), which are necessary for the shall and skeleton growth of certain marine life such as corals.
CO_3^{-2}
Phytoplankton: These tiny marine algae convert CO_2 into organic carbon through photosynthesis.
Larger organisms consume the plankton and release CO_2 through their breath and decomposition.
Deforestation: When forests are cut down, they can't absorb CO_2
Decomposing or burning timber releases CO_2 back into the atmosphere.
Coastal nutrient runoff from agriculture can lead to nearshore phytoplankton blooms.
Upwelling brings more acidic water to the surface in coastal zones.
As organisms descend and decay towards the sea floor CO_2 is released and seawater becomes more acidic.

Fig. 11.31: Process of Ocean Acidification

Effect of Ocean Acidification

Seawater absorbs CO_2, resulting in the production of carbonic acid (H_2CO_3), bicarbonate (HCO_3^-), and carbonate ions (CO_3^{2}). These carbonate ions play a crucial role in the calcification process, enabling marine organisms such as corals, molluscs, crustaceans, and plankton to build their calcium carbonate shells and skeletons. However, as atmospheric CO_2 levels increase, the pH level decreases while the concentrations of carbonic acid and bicarbonate ions increase, leading to a reduction in carbonate ion concentration. This has manyfold effects like:

- **Calcification Impairment:** Reduced carbonate ion concentration makes it harder for marine organisms such as corals, molluscs, and certain plankton species to build their calcium carbonate shells and skeletons. This can weaken their structures, making them more vulnerable to predation and environmental stress.
- **Disruption of Food Chains:** Calcifying organisms form the base of many marine food chains. Their decline due to ocean acidification can disrupt ecosystems, affecting the abundance and distribution of species throughout the food web.
- **Impact on Marine Biodiversity:** Ocean acidification threatens the survival of various marine species, including coral reefs, which support diverse ecosystems. Loss of biodiversity can destabilize marine habitats and reduce ecosystem resilience.
- **Altered Behavior and Physiology:** Acidification can affect the behavior and physiology of marine organisms, including fish, by interfering with sensory perception, reproduction, and growth. This can impair their ability to adapt to changing environmental conditions.
- **Economic Consequences:** Fisheries and aquaculture industries rely heavily on marine resources. Ocean acidification can affect fish populations and shellfish farming, leading to economic losses and livelihood challenges for coastal communities dependent on these industries.
- **Coral Bleaching and Reef Degradation:** Acidification exacerbates other stressors, such as rising sea temperatures, leading to coral bleaching events and reef degradation. This not only impacts marine biodiversity but also reduces the natural coastal protection provided by healthy coral reefs.
- **Carbon Cycling:** Changes in ocean chemistry affect the global carbon cycle. Ocean acidification can alter the solubility of CO_2 in seawater, potentially influencing atmospheric CO_2 levels and further exacerbating climate change.

Mitigation of Ocean Acidification

- Reducing carbon dioxide emissions globally,
- implementing sustainable fisheries management,
- protecting coastal habitats,

- reducing nutrient pollution,
- enhancing marine protected areas,
- investing in research and monitoring and promoting international collaboration.

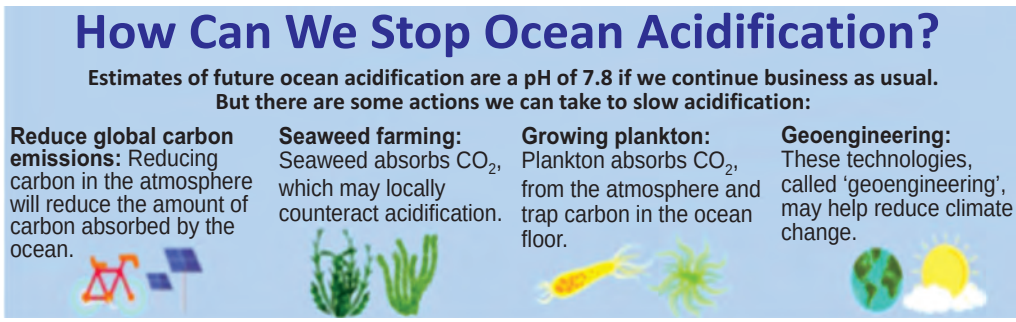

How Can We Stop Ocean Acidification?
Estimates of future ocean acidification are a pH of 7.8 if we continue business as usual.
But there are some actions we can take to slow acidification:
Reduce global carbon emissions: Reducing carbon in the atmosphere will reduce the amount of carbon absorbed by the ocean.
Seaweed farming: Seaweed absorbs CO_2, which may locally counteract acidification.
Growing plankton: Plankton absorbs CO_2, from the atmosphere and trap carbon in the ocean floor.
Geoengineering: These technologies, called 'geoengineering', may help reduce climate change.

Fig. 11.32: Process of Ocean Acidification

Short and Long-Term Impacts of Ocean Acidification on the Carbon Cycle

- In the short term, increased CO_2 levels lead to higher concentrations of carbonic acid in seawater, reducing the pH and carbonate ion availability. This affects marine organisms reliant on carbonate ions for shell and skeleton formation, potentially disrupting marine ecosystems.
- Over the long term, ocean acidification alters the distribution and cycling of carbon within the ocean. It can increase the solubility of calcium carbonate minerals, leading to enhanced dissolution of carbonate sediments and shells. This dissolution releases additional CO_2 into the water, exacerbating acidification in a positive feedback loop.
- Furthermore, changes in ocean chemistry affect the biological pump, the process by which marine organisms sequester carbon from the surface to the deep ocean through photosynthesis and sinking organic matter.
- Disruptions to this pump could impact the ocean's ability to absorb and store CO_2, influencing global climate regulation.
- Overall, ocean acidification alters the balance of carbon fluxes within marine ecosystems, with implications for both local biodiversity and the global carbon cycle. Addressing this issue requires reducing CO_2 emissions and implementing measures to protect and restore marine habitats.

Varied response of marine plants: The response of marine phytoplankton and plants to higher CO_2 levels varies. While some may experience increased growth and photosynthesis, this is not universally true.

- For certain species, elevated CO_2 and acidity can have negative or neutral effects on their physiology.
- As a result, certain marine plants may benefit while others may suffer, and some may remain unaffected, but change is inevitable.
- Reducing atmospheric CO_2 levels is crucial to mitigate ocean acidification before irreversible damage occurs.

CONTEMPORARY ISSUES IN NEWS
GLOBAL CLIMATE TRENDS(NASA)

- **CO_2:** Human activities have caused a 50% increase in atmospheric carbon dioxide levels in less than 200 years, surpassing the natural rise observed at the end of the last ice age 20,000 years ago.
  - The concentration of CO_2 reached a historic high of 422 parts per million (ppm) in December 2023. Seasonal cycles in photosynthesis drive the annual rise and fall of CO_2 levels.
  - During the Northern Hemisphere spring, plants absorb CO_2 for growth, reducing atmospheric CO_2. In autumn, plant activity decreases, leading to CO_2 release through decomposition. A similar pattern occurs in the Southern Hemisphere, albeit less intense, in opposite seasons.
- **Methane:** Over the past two centuries, atmospheric methane levels have more than doubled. Scientists attribute 20 to 30% of climate warming since the Industrial Revolution to this increase.
  - While natural processes contribute 40% of methane emissions, with wetlands being the largest natural source, human activities now account for approximately 60% of methane emissions.
  - Agriculture, fossil fuels, and landfill waste decomposition are the primary human-related sources of methane.
- **Temperature:** In 2023, the Earth's average surface temperature reached its highest level since record keeping began in 1880, with a recorded anomaly of 1.17°C above the long-term average. The ten most recent years are among the warmest on record.
- **Ocean Warming:** Ninety percent of global warming is taking place in the ocean, leading to increased internal heat within the water. This stored heat causes the water to expand, contributing to one-third to one-half of the global rise in sea levels.

- The majority of this added energy is concentrated near the surface, at depths ranging from zero to 700 meters.
- The past decade marked the warmest period for the ocean since at least the 1800s, with the year 2022 standing out as the warmest on record and experiencing the highest global sea levels.

❑ **Ice Sheets:** Antarctica is experiencing ice mass loss at an average rate of approximately 150 billion tons annually, while Greenland is losing around 270 billion tons per year, contributing to sea level rise.
- These ice sheets, holding about two-thirds of Earth's fresh water, are crucial. Meltwater from Greenland and Antarctica accounts for roughly one-third of the global average increase in sea level since 1993.

❑ **Sea Level Rise:** Sea levels are increasing due to human-induced global warming, with recent rates unmatched in the past 2,500 years. Since 1993, the rise has been measured at 100 (± 4.0) mm.

❑ **Arctic Sea Ice Minimum Extent:** Each September, Arctic sea ice reaches its minimum extent, defined as the area where satellite sensors detect at least 15% ice coverage per pixel. The September Arctic sea ice is currently decreasing by 12.2% per decade compared to its average extent from 1981 to 2010.

The Climate Action Tracker (CAT) is an independent scientific project that tracks government climate action and measures it against the globally agreed Paris Agreement aim of "holding warming well below 2°C, and pursuing efforts to limit warming to 1.5°C." A collaboration of two organizations, Climate Analytics and NewClimate Institute, the CAT has been providing this independent analysis to policymakers since 2009.

The Climate Group is an international non-profit which includes over 500 multinational businesses in 175 markets worldwide. It also works closely with governments at all levels. **The Under2 Coalition,** for which it is the Secretariat, is made up of 220+ state and regional governments and has been named one of the international cooperative initiatives with the highest potential for emissions reductions.

EP100 is a global corporate energy efficiency initiative, led by Climate Group, bringing together over 125 ambitious businesses committed to improving their energy efficiency.

Climate Change in the Himalayas

❑ **Precipitation and Glacier Response:** Climate change significantly affects precipitation patterns and glacier melting in the Himalayas. Melting glaciers alter runoff patterns of rivers, impacting over 500 million people downstream and various industries.

❑ **Consequences of Glacier Melting:** Glacier retreat threatens water sustainability for millions in countries like India. Increased pressure on water resources due to various factors exacerbates the impacts of glacier melting. Glacier melting contributes to floods, forest fires, and challenges water resource management.

❑ **Aerosol Impact on Himalayas- Radiative Forcing and Atmospheric Heating:** Aerosol radiative forcing efficiency (ARFE) in the Himalayan foothills is significantly higher compared to other polluted sites in South and East Asia.
- Annual mean aerosol-induced atmospheric heating rates are notably elevated, potentially accounting for over 50% of total warming in the lower atmosphere and surface over this region.

❑ **Current Situation and Trends:** Glacial melting in the Himalayas has accelerated in recent decades due to rising temperatures. The number of glaciers has increased due to fragmentation, indicating significant ice loss. Warming temperatures and erratic weather patterns pose severe threats to water sources and livelihoods in the region.
- Temperatures in the vast high mountain region, including the Hindu Kush Himalayas, have risen significantly since the 20th century.

❑ **Connection to Monsoon and Regional Impacts:** Disruption of monsoons affects glacier replenishment and leads to flooding, impacting agriculture and hydroelectricity. Weaker monsoons exacerbate water scarcity and desertification, posing challenges for regional development.

❑ **Latest Research Findings:** Recent studies reveal alarming trends in Himalayan glacier melting, with billions of tonnes of ice lost annually since the 1970s. Rising temperatures and changes in precipitation patterns are major contributors to accelerated ice loss.

❑ **Causes of Glacier Melting:** Human-induced climate change, primarily driven by greenhouse gas emissions, is the main cause of glacier melting. Local factors like air pollution and infrastructure development also contribute to glacier retreat.

❑ **Impacts of Glacier Melting:** Glacier melting leads to extreme flooding, loss of biodiversity, and habitat destruction. Economic costs, freshwater scarcity, and disruptions to ocean currents are global consequences of glacier retreat.

❑ **Future Challenges and Outlook:** Continued glacier melting poses threats to water resources, biodiversity, and regional stability. Urgent mitigation efforts and global cooperation are needed to address the impacts of glacier melting on ecosystems and livelihoods.

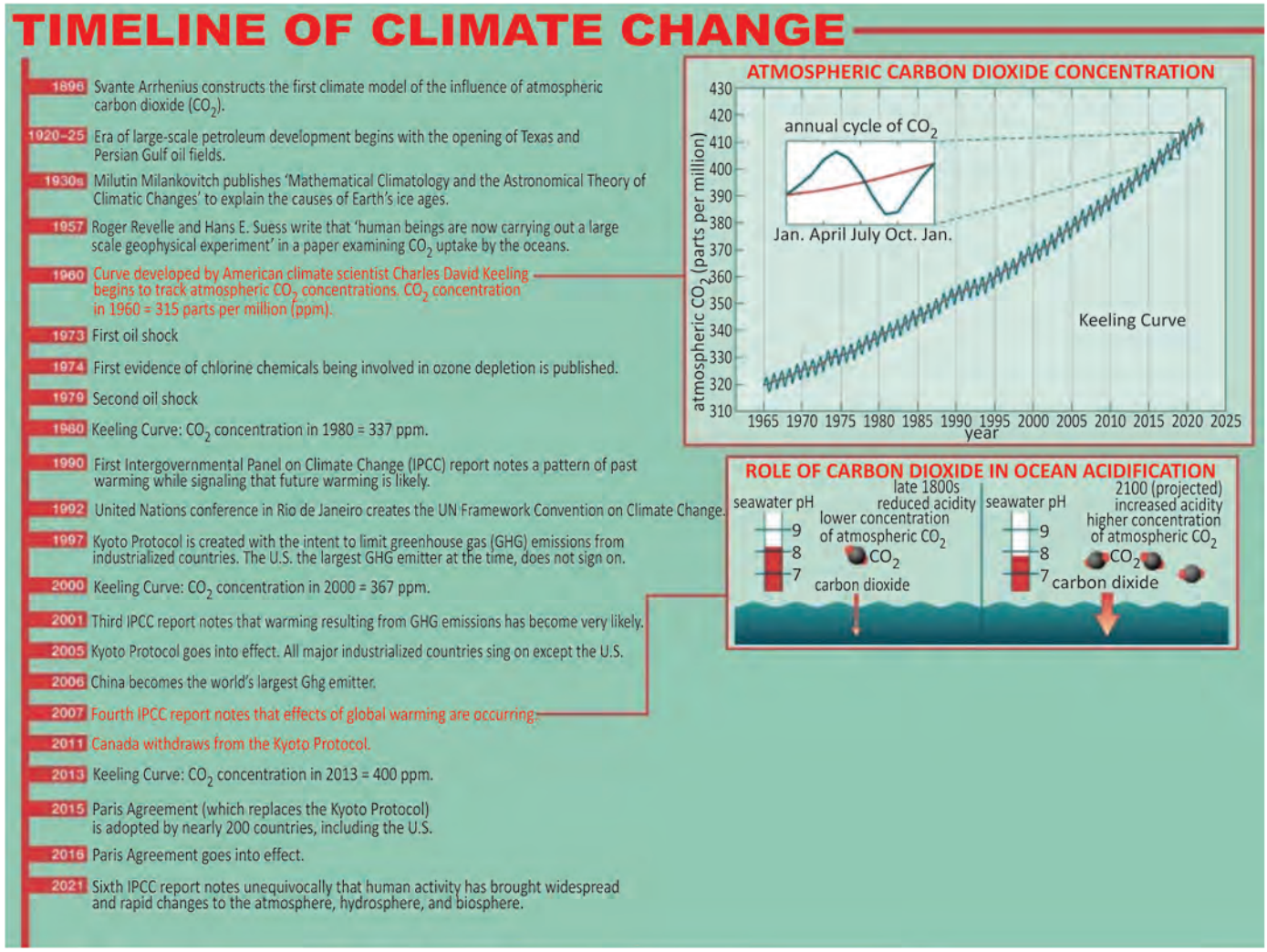

TIMELINE OF CLIMATE CHANGE
1896 Svante Arrhenius constructs the first climate model of the influence of atmospheric carbon dioxide (CO_2).
1920–25 Era of large-scale petroleum development begins with the opening of Texas and Persian Gulf oil fields.
1930s Milutin Milankovitch publishes 'Mathematical Climatology and the Astronomical Theory of Climatic Changes' to explain the causes of Earth's ice ages.
1957 Roger Revelle and Hans E. Suess write that 'human beings are now carrying out a large scale geophysical experiment' in a paper examining CO_2 uptake by the oceans.
1960 Curve developed by American climate scientist Charles David Keeling begins to track atmospheric CO_2 concentrations. CO_2 concentration in 1960 = 315 parts per million (ppm).
1973 First oil shock
1974 First evidence of chlorine chemicals being involved in ozone depletion is published.
1979 Second oil shock
1980 Keeling Curve: CO_2 concentration in 1980 = 337 ppm.
1990 First Intergovernmental Panel on Climate Change (IPCC) report notes a pattern of past warming while signaling that future warming is likely.
1992 United Nations conference in Rio de Janeiro creates the UN Framework Convention on Climate Change.
1997 Kyoto Protocol is created with the intent to limit greenhouse gas (GHG) emissions from industrialized countries. The U.S. the largest GHG emitter at the time, does not sign on.
2000 Keeling Curve: CO_2 concentration in 2000 = 367 ppm.
2001 Third IPCC report notes that warming resulting from GHG emissions has become very likely.
2005 Kyoto Protocol goes into effect. All major industrialized countries sing on except the U.S.
2006 China becomes the world's largest Ghg emitter.
2007 Fourth IPCC report notes that effects of global warming are occurring.
2011 Canada withdraws from the Kyoto Protocol.
2013 Keeling Curve: CO_2 concentration in 2013 = 400 ppm.
2015 Paris Agreement (which replaces the Kyoto Protocol) is adopted by nearly 200 countries, including the U.S.
2016 Paris Agreement goes into effect.
2021 Sixth IPCC report notes unequivocally that human activity has brought widespread and rapid changes to the atmosphere, hydrosphere, and biosphere.
ATMOSPHERIC CARBON DIOXIDE CONCENTRATION
annual cycle of CO_2
Jan. April July Oct. Jan.
Keeling Curve
atmospheric CO_2 (parts per million)
430 420 410 400 390 380 370 360 350 340 330 320 310
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025
year
ROLE OF CARBON DIOXIDE IN OCEAN ACIDIFICATION
seawater pH
9 8 7
late 1800s
reduced acidity
lower concentration of atmospheric CO_2
CO_2
carbon dioxide
seawater pH
9 8 7
2100 (projected)
increased acidity
higher concentration of atmospheric CO_2
CO_2
carbon dioxide

Fig. 11.33: The Timeline of Climate Change

CONCLUSION

In this chapter, we have explored the multifaceted dimensions of climate change and global warming, unraveling their far-reaching impacts on ecosystems, communities, and livelihoods worldwide. From rising temperatures and extreme weather events to shifting precipitation patterns and melting ice caps, the evidence of climate change's disruptive force is undeniable.

As we confront the urgent challenges posed by climate change, it becomes increasingly clear that mitigation and adaptation are essential pillars of our response. While mitigation efforts aim to reduce greenhouse gas emissions and curb the drivers of climate change, adaptation strategies focus on building resilience and adapting to the changes already underway.

Looking ahead, the next chapter will delve into the intricacies of mitigation and adaptation, exploring innovative solutions and pragmatic approaches to address climate change's existential threat. By embracing a holistic approach that integrates science, policy, and community engagement, we can pave the way towards a more sustainable and resilient future for generations to come.

Climate Change Management/ Mitigation and Adaptation

12

INTRODUCTION

Climate change stands as a profoundly intricate challenge that confronts humanity today. It encompasses various realms such as science, economics, society, politics, and moral considerations. Its impacts are felt globally and will persist locally for millennia. Carbon dioxide, the predominant greenhouse gas fueling recent global warming, remains in the atmosphere for extended periods, while the planet, particularly the oceans, responds gradually to temperature increases. Even if greenhouse gas emissions were to suddenly stop, Earth's surface temperature would require thousands of years to cool and return to the level in the pre-industrial era, consequently affecting future generations. Thus, humanity is irrevocably "committed" to experiencing some degree of climate change.

The extent of this change hinges on the trajectory of our emissions and the subsequent response of the climate system. Despite heightened awareness, greenhouse gas emissions persistently escalate. In 2013, daily atmospheric carbon dioxide levels exceeded 400 parts per million, an unprecedented occurrence in human history. Such levels have not been recorded for three to five million years, dating back to the Pliocene Epoch.

Given our existing commitment to climate change, addressing it necessitates a dual strategy: **Mitigation** and **Adaptation**.

Climate Change Mitigation Vs Adaptation

Aspect	Mitigation	Adaptation
What it means	Reduce our emissions and enhance sinks that sequester and store greenhouse gases to achieve Net Zero	Adjust to expected and actual effects of climate change to reduce vulnerability
What it does	Addresses the root cause	Addresses the effect
Goals	Avoid the negative impact of climate change	Reduce risk and increase the ability to prepare, absorb and recover from adverse climate events (enhance resilience). Increase our capacity to thrive under adverse climate conditions
Focus	Global impact	Local, start with the specific local situation
Geographies	The Global North that has the highest emissions	The Global South already experiences the effects and is more vulnerable to climate change
Examples	Clean energy, energy efficiency, sustainable transportation, etc.	Disaster management, flood protection, infrastructure upgrades, etc.

Climate Change Mitigation

Mitigation aims to reduce climate change by limiting the release of heat-trapping greenhouse gases into the atmosphere.

- This can be achieved by curbing emissions from various sources like fossil fuel combustion for energy or transportation and by bolstering natural carbon sinks such as oceans, forests and soil.
- The objective is to prevent significant human interference with Earth's climate, stabilize greenhouse gas levels within a time-frame conducive to natural ecosystem adaptation, safeguard food production, and promote sustainable economic development. (Based on AR5 Climate Change 2014: Mitigation of Climate Change)

Climate Change Adaptation

Adaptation refers to adjusting to the realities of a changing climate, whether current or anticipated. The objective is to minimize risks posed by adverse effects of climate change, such as rising sea levels, heightened extreme weather events, or food shortages.

- Additionally, adaptation involves seizing potential opportunities that may arise from climate change, such as extended growing seasons or enhanced yields in certain regions.

Climate Change Mitigation Vs Adaptation

The major differences between mitigation and adaptation have been outlined in the table.

- While mitigation efforts take time to yield results and impact temperature rise over the long term, adaptation measures are essential for dealing with the immediate and ongoing impacts of climate change.
- By implementing both mitigation and adaptation strategies, we can better prepare for the challenges ahead and work towards a more resilient future.
- Certain measures, such as water conservation, educational initiatives and nature-based solutions like wetland restoration, encompass aspects of **both mitigation and adaptation** strategies.
- **Mitigation takes precedence:** To prevent sinking due to the climate crisis, it is imperative to advocate for action. While adaptation efforts are crucial, addressing the root cause and repairing the fundamental issues, akin to fixing the hole in our boat, is paramount.
  - Understanding the true underlying causes is essential; perhaps it is not merely the leak but also the production process of the boat itself. An economic system prioritizing growth above all may pose greater harm than individual factors like plastic straws.
- **Preparation is the key:** The impacts of the climate crisis are evident and expected to exacerbate in the foreseeable future. According to **Henry Neufeldt**, the **chief editor** of the Adaptation Gap Report of the United Nations Environment Programme (UNEP), "adaptation remains imperative even if emissions were halted today."

STRATEGIES FOR CLIMATE CHANGE MITIGATION

Mitigation strategies focus on reducing greenhouse gas (GHG) emissions, which are the primary drivers of climate change. These gases, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), trap heat in the Earth's atmosphere, leading to global warming. By curbing emissions and enhancing carbon sequestration, mitigation efforts aim to stabilize the climate and minimize its adverse effects on ecosystems, economies, and societies.

Key Components of Strategies for Climate Change Mitigation Include

- **Transitioning to Renewable Energy:** Transitioning to renewable energy sources like solar, wind, hydroelectric, and geothermal power is crucial for reducing carbon emissions. Investments in renewable energy infrastructure and supportive policies can speed up this transition.
- **Energy Efficiency:** Improving energy efficiency in transportation, buildings, industry, and agriculture can significantly cut energy consumption and emissions. Technologies like energy-efficient appliances, fuel-efficient vehicles, and building insulation are key to reducing energy waste and carbon footprints.
- **Sustainable Land Use and Forestry:** Protecting and restoring forests, wetlands and ecosystems, which act as natural carbon sinks, absorbing CO_2. Sustainable land management practices like afforestation, reforestation, and agroforestry enhance carbon sequestration and biodiversity conservation while curbing deforestation and land degradation.
- **Climate-Friendly Agriculture and Carbon Pricing Market Mechanisms:** Implementing carbon pricing mechanisms, such as carbon taxes and cap-and-trade systems, can internalize the costs of carbon emissions and incentivize businesses and individuals to reduce their carbon footprint.
  - These market-based approaches provide economic incentives for investing in low-carbon technologies and transitioning to sustainable practices.
- **Investment in Research and Innovation:** Continued investment in research, development, and deployment of low-carbon technologies and innovative solutions is essential for driving progress in climate change mitigation.
  - Advancements in areas such as renewable energy, energy storage, carbon capture and storage (CCS), and sustainable agriculture can unlock new opportunities for emissions reduction.
- **International Cooperation and Policy Frameworks:** Addressing climate change requires collaborative efforts at the global level, with countries committing to ambitious emission reduction targets under international agreements such as the Paris Agreement.
  - Multilateral cooperation, along with robust national climate policies and regulations, is essential for achieving collective mitigation goals and building resilience to climate impacts.

Based on the above principles, the strategies available for climate mitigation can be broadly classified into:

- **Regulation-based Mitigation:** These are government-imposed policies and laws aimed at curbing greenhouse gas emissions and promoting sustainable practices across various sectors such as energy, transportation, industry and agriculture.
  - **Examples** include carbon pricing mechanisms, emission standards, renewable energy mandates, and land-use regulations. Regulations provide clear guidelines and incentives for reducing emissions but require effective enforcement and may face opposition.

- **Technology-based Mitigation:** Innovation-driven approaches focused on developing and deploying cleaner alternatives to fossil fuels, improving energy efficiency, and enhancing carbon capture and storage capabilities.
  - It includes advancements in renewable energy technologies, energy efficiency measures, carbon capture and storage, and sustainable agriculture practices. Investment in research, supportive policies, and international collaboration are crucial for scaling up these technologies to mitigate climate change effectively.

IGNITE YOUR MIND

Climate Clash of the Titans: Imagine a high-stakes negotiation between Captain Carbon, the embodiment of the fossil fuel industry, and Eco-Knight, the champion of renewable energy. Can they find common ground and forge a path toward a sustainable future, or are they destined for an epic clash?

Regulation Based Strategies

Carbon Credit

A Carbon credit represents the right to emit one tonne of carbon or carbon dioxide equivalent (CO_2e) and is tradable in markets. When an organization emits one tonne less of carbon or carbon dioxide equivalent than the standard emission level allowed, it earns a carbon credit.

- This system helped companies comply with emission norms set by signatory countries to the Kyoto Protocol under the UNFCCC by 2012.
- Companies can reduce emissions by two major ways:
  - Adopting new technologies or improving existing ones, or
  - They can collaborate with developing nations to implement eco-friendly technologies and earn credits in the process.
- These credits serve as permits for the company to emit greenhouse gases in its own country.
- However, only a portion of the carbon credits from a company in a developing country can be transferred to a company in a developed country.

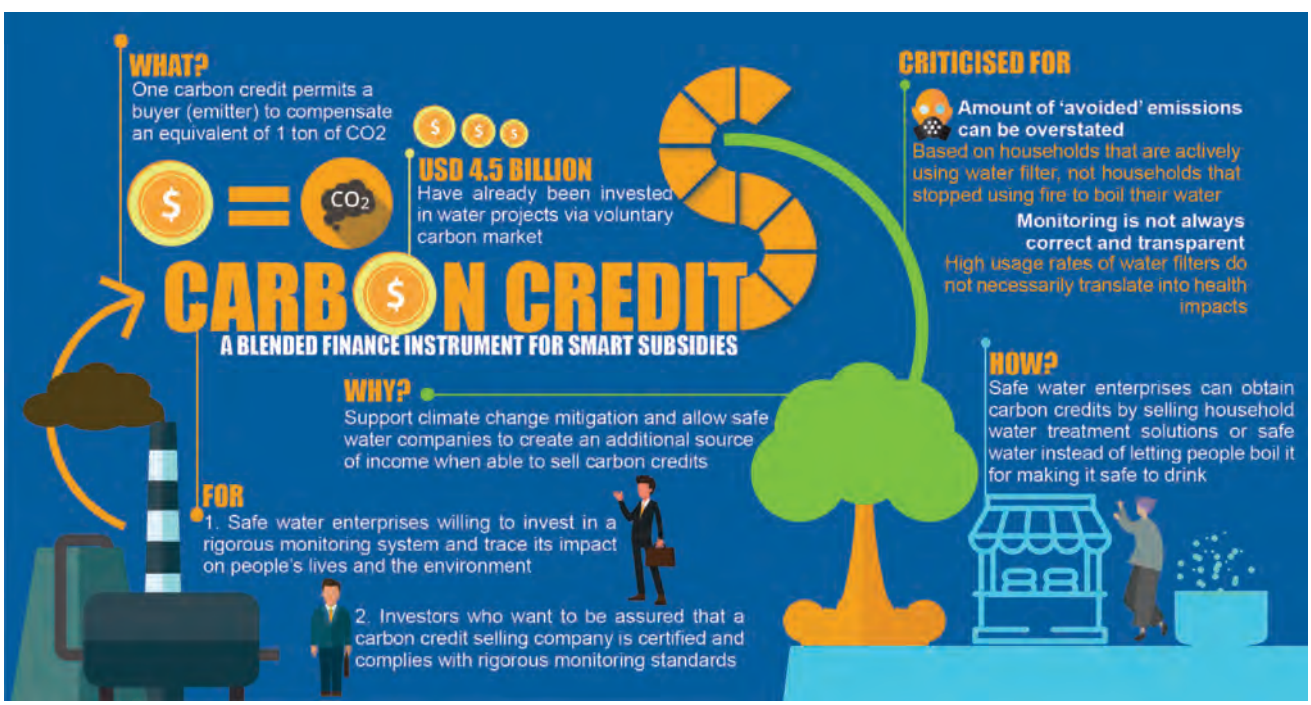

WHAT?
One carbon credit permits a buyer (emitter) to compensate an equivalent of 1 ton of CO2
USD 4.5 BILLION
Have already been invested in water projects via voluntary carbon market
CARBON CREDIT
A BLENDED FINANCE INSTRUMENT FOR SMART SUBSIDIES
WHY?
Support climate change mitigation and allow safe water companies to create an additional source of income when able to sell carbon credits
FOR
1. Safe water enterprises willing to invest in a rigorous monitoring system and trace its impact on people's lives and the environment
2. Investors who want to be assured that a carbon credit selling company is certified and complies with rigorous monitoring standards
CRITICISED FOR
Amount of 'avoided' emissions can be overstated
Based on households that are actively using water filter, not households that stopped using fire to boil their water
Monitoring is not always correct and transparent
High usage rates of water filters do not necessarily translate into health impacts
HOW?
Safe water enterprises can obtain carbon credits by selling household water treatment solutions or safe water instead of letting people boil it for making it safe to drink

Fig 12.1: Carbon Credit

- **Types of Carbon Credits:**
  - **Voluntary Emissions Reduction (VER):** Carbon offsets exchanged in the voluntary market for credits.
  - **Certified Emissions Reduction (CER):** Credits generated through a regulatory framework to offset emissions from a project.

Carbon Markets

Carbon markets facilitate the buying and selling of carbon emission rights to reduce global greenhouse gas emissions. They enable emissions reductions beyond individual country efforts.

Example: A factory in India can reduce emissions by receiving technology or financial aid from another country, or by investing in emission reduction measures and selling resulting reductions as Carbon Credits. Entities unable to meet their emission targets can purchase these credits to offset their own emissions.

- **Carbon Credit Market under the Paris Agreement:** The carbon market, which initially operated under the Kyoto Protocol, underwent a transition with the advent of the Paris Agreement in 2015. While the core elements of Article 6 were agreed upon in 2015, the specific rules and regulations for its operation are still under development.

Various Carbon Markets

1. **Compliance or Mandatory Markets:** They are regulated by national, regional, or international policies and operate based on the "cap-and-trade" principle. An example of this is the EU's emissions trading system **(EU ETS).**
   - Established in 2005, the EU ETS sets emissions caps for sectors like power, manufacturing, and agriculture, allocating permits accordingly.
   - Entities exceeding their allowances must purchase additional permits, driving emissions trading and determining carbon prices through market dynamics.
2. **Voluntary Markets:** In voluntary carbon markets, emitters purchase carbon credits to offset their emissions, typically originating from activities like afforestation. These credits are bought from projects that reduce, capture, remove, or avoid greenhouse gas emissions.

Global Carbon Markets Status

The value of traded global markets for carbon dioxide (CO_2) permits reached a record 881 billion euros ($948.75 billion) in 2023. Around 12.5 billion metric tons of carbon permits changed hands in the world's emissions markets, similar to 2022, but record prices in several markets such as Europe and North America pushed up the overall value, according to the LSEG Carbon Market Year in Review 2023. The world's most valuable carbon market, the EU's ETS, was worth around 770 billion euros last year, up 2% from the previous year and representing 87% of the global total.

- Trading in carbon credits has the potential to halve the cost of implementing NDCs by 2030, potentially saving up to USD 250 billion, according to the World Bank.

India Carbon Market Status

- India's carbon credit market boasts a value exceeding US $1.2 billion, making it the world's **second largest.**
- In India, carbon markets are primarily driven by the **Clean Development Mechanism** under the Kyoto Protocol, with secondary schemes like the perform-achieve-trade and renewable energy certificates.

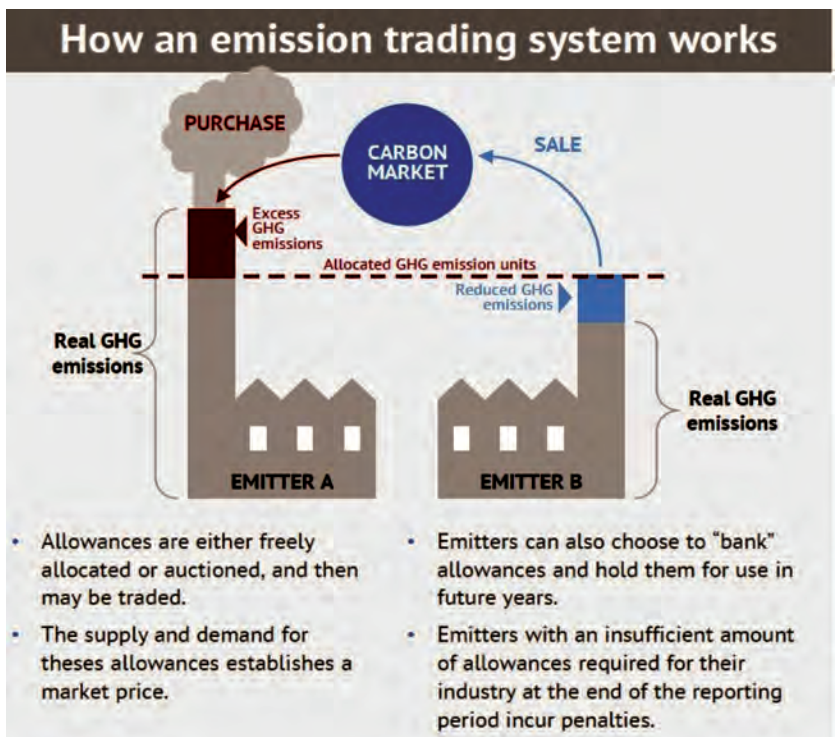

How an emission trading system works
PURCHASE
CARBON MARKET
SALE
Excess GHG emissions
Allocated GHG emission units
Reduced GHG emissions
Real GHG emissions
Real GHG emissions
EMITTER A
EMITTER B
Allowances are either freely allocated or auctioned, and then may be traded.
The supply and demand for theses allowances establishes a market price.
Emitters can also choose to "bank" allowances and hold them for use in future years.
Emitters with an insufficient amount of allowances required for their industry at the end of the reporting period incur penalties.

Fig 12.2: Emission Trading System

Indian Carbon Market: The government aims to establish the **Indian Carbon Market (ICM)** as part of its strategy to decarbonize the Indian economy.

- This initiative involves creating a national framework focused on pricing greenhouse gas (GHG) emissions through the trading of Carbon Credit Certificates.
- Led by the **Bureau of Energy Efficiency** under the **Ministry of Power**, in collaboration with the **Ministry of Environment, Forest & Climate Change**, the **Carbon Credit Trading Scheme** is being developed to facilitate this objective.

- The ICM is expected to foster a competitive market environment, encouraging climate actors to adopt cost-effective solutions.
- By attracting technology and finance toward sustainable projects that generate carbon credits, the market will incentivize low-carbon options.
- Moreover, it is envisioned as a key mechanism for mobilizing significant investments needed for India's transition to low-carbon pathways.

Challenges to Carbon Markets

- **Lack of Market Integrity:** The UNDP raises concerns about the integrity of the market due to issues such as double counting of emissions reductions and doubts about the quality of carbon projects.
- **Greenwashing:** Some companies may use carbon credits to offset their emissions without significant emission reduction efforts or investment in cleaner technologies.
- **Potential Net Emission Increase through ETS:** IMF warns that including high-emission sectors in Emissions Trading Systems could lead to a net increase in emissions, with absence of any self-regulating mechanism in case of cost-inefficient projects.

Way Forward

- The UNDP underscores the importance of ensuring that emission reductions and removals are genuine and in line with the country's Nationally Determined Contributions (NDCs) for carbon markets to succeed.
- Additionally, there must be transparency in the institutional and financial framework governing carbon market transactions.

Carbon Offsetting

Carbon offsets are credits earned for greenhouse gas reductions elsewhere, like from wind farms replacing fossil-fuel energy. Measured in metric tonnes of CO_2e, one tonne offsets one tonne of CO_2.

- Offset projects can bring benefits like job opportunities and community development. To be credible, offsets must show additionality, retire to prevent double counting, and address permanence and leakage issues. They are an efficient way for businesses to cut emissions.

Illustration of Carbon Offsetting: Let us consider EcoTech, a manufacturing company emitting 10,000 metric tons of CO_2e annually.

- To offset its emissions, EcoTech invests in a reforestation project that sequestrates 5,000 metric tons of CO_2.
- By purchasing carbon credits equal to the sequestered amount, EcoTech effectively offsets its carbon footprint.
- This enables EcoTech to claim carbon neutrality for the year, as its net emissions, after offsetting, are zero.

Types of Carbon Offsets

- **Tree Planting Initiatives:** Combat deforestation by planting trees in developing countries to absorb CO_2.
- **Forest Conservation:** Protect existing forests, especially in regions reliant on wood for heating, by funding alternatives and providing efficient cooking equipment.
- **Soil Management:** Improve soil health damaged by intensive farming to enhance CO_2 absorption and reduce nitrous oxide emissions through methods like cover cropping and reduced machine traffic.
- **Renewable Energy Investment:** Direct financing of solar and wind farms reduces fossil fuel reliance, contributing significantly to emission reductions.
- **Energy Efficiency Programs:** Reduce overall energy demand by modernizing fossil-fuel plants, upgrading engines, and retrofitting buildings for improved efficiency.
- **Methane Capture and Combustion:** Capture methane emissions from sources like landfills and farms, burning it or using it for electricity generation to reduce its greenhouse gas impact.

Carbon Tax: Alternative to Emission Control

Carbon tax is considered a potential alternative to the current 'cap and trade' method used by the protocol, based on the carbon content of fuels like coal. Its aim is to reduce fossil fuel use, encouraging the adoption of alternative energy sources. If implemented, the tax would start gradually and increase over time, allowing for the development of better industry and technology.

Here are five primary reasons why a carbon tax could be more beneficial than the 'cap and trade' system:

- **Predictability:** The tax could help predict energy prices, fostering investments in energy efficiency and alternative fuels.
- **Implementation:** A carbon tax could be implemented more quickly compared to the complexities of the 'cap and trade' method.
- **Understandability:** The carbon tax is simpler to understand and may be more readily embraced by the general public.
- **Lack of Manipulation:** Special interest groups have less opportunity to manipulate a carbon tax due to its simplicity.
- **Rebates:** Similar to other taxes, the carbon tax could allow for rebates to the public.

The European Union's (EU) plan to introduce a **Carbon Border Adjustment Mechanism (CBAM)** starting from January 1, 2026, serves as a real-world example of the implementation of a carbon tax. The **coal cess**, implemented in 2010, currently stands at **Rs.400 per tonne**, which is nearly one-fifth of the coal mining cost. This levy serves as India's equivalent of a carbon tax.

India's stance on carbon tax: India plans to contest any "carbon taxes" imposed by wealthy nations on Indian imports through the WTO dispute settlement forum.

- The Minister of Environment, Forests, and Climate Change emphasized that such barriers would not align with WTO rules, and India aims to negotiate solutions.
- The US and EU have considered imposing tariffs or "border carbon adjustments" on imports from countries with less stringent greenhouse gas emission regulations.

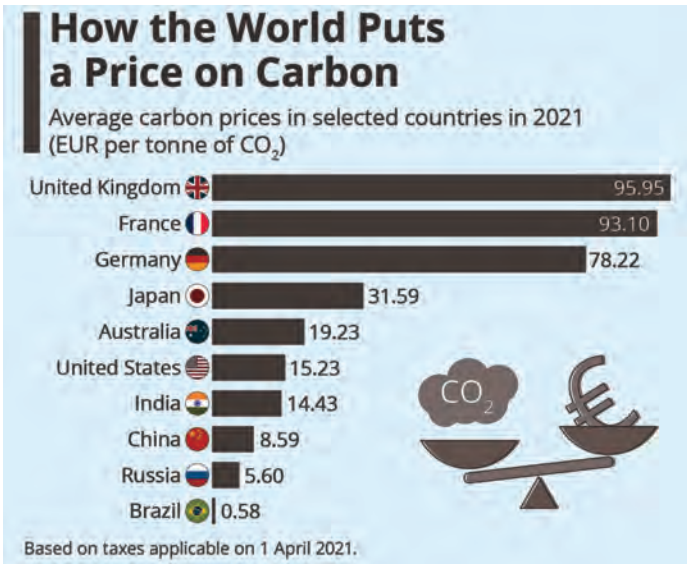


Fig 12.4: Carbon pricing policies in selected countries

IGNITE YOUR MIND

Carbon Pricing Challenge: Design a fair and effective carbon pricing scheme that incentivizes polluters to reduce their emissions without crippling the economy. Can you create a system that rewards responsible businesses and protects vulnerable communities?

Climate Technologies

Clean Coal Technology

Clean coal technology refers to a range of technologies and techniques aimed at reducing the environmental impact of coal-based energy production. The primary goal is to minimize the emission of pollutants, including greenhouse gases (GHGs), sulphur dioxide (SO_2), nitrogen oxides (NOx), and particulate matter, while still utilizing coal as a fuel source. This includes optimizing coal preparation, selecting efficient combustion technologies, and implementing carbon capture during post-combustion processes.

Need for Clean Coal Technologies: Clean coal technology is need of the hour due to factors like:

- **Abundant Resource:** Coal, comprising 37% of global energy, necessitates Clean Coal Technologies (CCTs) to sustainably harness its potential.
- **Environmental Impact:** Coal combustion emits pollutants like SO2, NOx, and CO_2, exacerbating local and global environmental issues. CCTs mitigate emissions, reducing environmental harm.
- **Climate Change:** Coal-fired plants emit around 15 billion tonnes of CO_2 annually. Enhancing plant efficiency via CCTs can significantly curb CO_2 emissions, aiding climate change mitigation.
- **Sustainable Development:** Improving coal plant efficiency to 40% could slash CO_2 emissions, fostering economic growth and energy access while mitigating health and environmental impacts. Deploying CCTs is crucial for sustainable development and emissions reduction.

Types of Clean Coal Technologies

Clean Coal Technologies (CCTs) encompass two main categories: High efficiency Low Emission Technologies and Carbon Capture, Utilisation and Storage.

- **High Efficiency Low Emission (HELE)** technologies enhance the efficiency of coal-fired power plants and mitigate CO_2 and other greenhouse gas (GHG) emissions primarily during pre-combustion and combustion stages.
  - **Coal washing:** This process involves removing impurities from coal before it is burned, reducing emissions of sulfur dioxide and other pollutants.
  - **Fluidized bed combustion:** This technology burns coal at lower temperatures and mixes it with limestone or dolomite to capture sulfur dioxide emissions.
  - **Integrated gasification combined cycle (IGCC):** IGCC converts coal into a synthetic gas (syngas) that is used to generate electricity. This process allows for the capture of carbon dioxide emissions for storage or utilization.
  - **Flue-gas desulfurization (FGD)** Also known as scrubbing, the process regulates coal combustion to reduce sulfur dioxide, nitrogen oxides, and particulate emissions.
    - This process involves spraying limestone and water onto the flue gas (or power plant exhaust), causing a reaction that converts sulfur dioxide into synthetic gypsum.
    - This gypsum can then be utilized in the production of drywall and other environmentally friendly construction materials.
  - **Co-firing:** Co-firing involves combusting coal along with biomass or other renewable fuels to reduce emissions and increase fuel flexibility.
- **Carbon Capture, Use & Storage (CCUS)** technologies, which operate across both pre- and post-combustion stages. CCS technologies capture carbon dioxide emissions from coal-fired power plants and other industrial sources, preventing them from entering the atmosphere. The captured CO_2 is then transported and stored underground in geological formations.

- **Capture Technologies:**
  - **Pre-Combustion Capture:** Involves capturing CO_2 from an intermediate reaction in a conversion process, like during gasification, using methods such as physical and chemical adsorption.
  - **Post-Combustion Capture:** Separates CO_2 from waste gas streams after converting the carbon source, employing techniques like absorption, membrane filtration, adsorption, and cryogenic separation.
  - **Oxy-Fuel Combustion:** It Involves burning fuel with pure oxygen to produce CO_2-rich flue gas, suitable for various combustion processes, eliminating nitrogen and its compounds.
- **Storage:** Appropriate storage locations for captured carbon encompass former gas and oil fields, deep saline formations (porous rocks saturated with highly saline water), coal bed formations, and ocean beds.
- **Utilization:** Captured CO_2 can be utilized as a commercial product, directly or after conversion, in various industries:
  - **Food and drink industry:** as a carbonating agent, preservative, packaging gas, solvent for flavor extraction, and in decaffeination.
  - **Pharmaceutical industry:** as a respiratory stimulant and in drug synthesis.
  - **Concrete building materials:** for cement curing and aggregate manufacture.
  - **Enhanced oil and coal-bed methane recovery:** injected into depleting reserves to increase recovery.
  - **Chemicals, plastics, and fuels production:** including methanol, urea, polymers, and syngas.
  - **Mineral carbonation:** CO_2 reacts with metal oxides to form carbonates.
  - **Biofuels production:** used to cultivate microalgae for biofuel production.

Clean coal technologies can mitigate the environmental impact of coal-fired power, yet face challenges. High implementation costs and early-stage development of technologies like CCS (Carbon Capture and Storage) pose hurdles. Moreover, coal combustion inherently produces emissions, making clean coal a transitional, not long-term, energy solution.

IGNITE YOUR MIND

Clean Coal Conundrum: Is clean coal a mythical beast or a potential solution lurking in the shadows? Can technological advancements truly transform this climate villain into a force for good, or is it destined to remain an environmental nightmare?

Carbon Sequestration

Carbon sequestration, or carbon capture and storage (CCS), involves capturing CO_2 emissions from power plants, industries, or the atmosphere and storing it underground permanently.

- It aims to mitigate global warming by reducing greenhouse gas accumulation from fossil fuel combustion. Sequestration utilizes both natural and artificial **"carbon sinks,"** like oceans, forests, or depleted oil reserves.
- Initially utilized in oil and gas industries for recovery, carbon capture has recently gained attention for environmental purposes.

There are three main steps involved in CCS:

- **Capture and Separation:** This involves trapping and separating CO_2 from other gases emitted during industrial processes or power generation.
- **Transportation:** The captured CO_2 is then transported to a storage location, usually via pipelines or other means.
- **Storage:** The CO_2 is stored underground or deep in the ocean, away from the atmosphere, to prevent it from contributing to global warming.

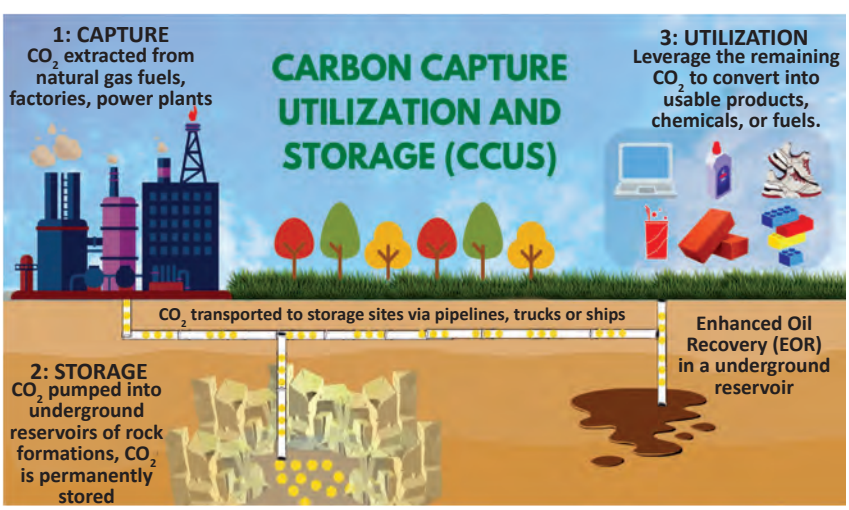

1: CAPTURE
CO2 extracted from natural gas fuels, factories, power plants
CARBON CAPTURE UTILIZATION AND STORAGE (CCUS)
3: UTILIZATION
Leverage the remaining CO2 to convert into usable products, chemicals, or fuels.
CO2 transported to storage sites via pipelines, trucks or ships
Enhanced Oil Recovery (EOR) in a underground reservoir
2: STORAGE
CO2 pumped into underground reservoirs of rock formations, CO2 is permanently stored

Fig 12.5: Carbon Capture Utilization and Storage (CCUS)

Carbon sequestration can be carried out through various methods:

- **Ocean Sequestration:** It involves injecting CO_2 directly into the ocean or using fertilization techniques to enhance carbon uptake by marine organisms.
- **Terrestrial Sequestration:** It enhances carbon uptake in natural sinks such as **soils and vegetation** through measures like increasing photosynthesis or reducing organic matter decomposition.
- **Geological sequestration**, which utilizes hydrodynamic trapping, solubility trapping, and mineral carbonation mechanisms, is considered the most promising near-term option for large-scale carbon storage.
  - In **hydrodynamic trapping**, CO_2 is stored as a gas beneath low-permeability cap rocks, similar to natural gas storage.
  - **Solubility trapping** involves dissolving CO_2 into liquids such as water or oil.
  - **Mineral carbonation** occurs when CO_2 reacts with minerals in geological formations to form stable compounds.
- **Potential Sites for Carbon Sequestration:** Abandoned and uneconomic coal seams, depleted oil and gas reservoirs, subterranean deep saline formations.

Overall, carbon sequestration technologies offer promising solutions for reducing greenhouse gas emissions and mitigating climate change impacts.

Carbon Sink

- A **carbon sink** is any reservoir, whether natural or man-made, that absorbs and stores more carbon dioxide (CO_2) from the atmosphere than it releases, thus reducing atmospheric CO_2 concentrations.

IGNITE YOUR MIND

Carbon Capture Caper: Become a carbon detective on a mission to capture elusive carbon dioxide molecules wreaking havoc on the atmosphere. What innovative tools and strategies can you use to succeed? Is carbon capture a game-changer, or just a temporary fix?

- **Natural carbon sinks**, such as forests, oceans, and soil, absorb CO_2 through processes like photosynthesis or chemical absorption.
- **Artificial carbon sinks**, like **carbon capture and storage (CCS)** technologies, capture CO_2 emissions from industrial processes and store them underground to prevent their release into the atmosphere.
- The **two most significant** carbon sinks globally are **vegetation and the ocean**.

Natural Carbon SInks

- **Forests:** Essential for regulating CO_2 levels, forests facilitate photosynthesis, converting carbon dioxide into glucose and releasing oxygen. Photosynthesis accounts for roughly half of atmospheric carbon removal.
- **Soil:** Rich in organic matter, soil absorbs CO_2 as plants grow, and carbon is further deposited through decaying plant matter. Earth's soil absorbs about a quarter of human emissions annually, with significant storage in peatland and permafrost.
- **Oceans:** Oceans absorb approximately a quarter of CO_2 emissions, aided by biological processes like phytoplankton photosynthesis. Phytoplankton play a crucial role in carbon sequestration, although plastic pollution threatens their effectiveness.

IGNITE YOUR MIND

The Mitigation Maze: You're trapped in a labyrinth of climate solutions, each with its own advantages and drawbacks. Can you navigate through clean coal, carbon capture, and carbon pricing to escape and unlock a sustainable future? What are the hidden costs and ethical dilemmas of each path?

Green and Blue Carbon

Green Carbon: Refers to carbon absorbed by photosynthesis and stored in plants and soil, playing a vital role in the global carbon cycle. Forests accumulate carbon over decades, making afforestation and reforestation effective strategies.

Blue Carbon: Encompasses coastal, aquatic, and marine carbon sinks found in vegetation, marine organisms, and sediments. Coastal ecosystems efficiently sequester carbon, storing vast quantities in plants and sediment.

- **Importance of Blue Carbon Ecosystems:** Protecting coastal ecosystems like mangroves and tidal marshes is crucial for climate mitigation. Their degradation halts carbon sequestration and releases stored carbon, exacerbating climate change.

While black and brown carbon contribute to atmospheric greenhouse gases, green and blue carbon help sequester these gases from the atmosphere.

Geo-Engineering

Geoengineering refers to deliberate and large-scale interventions in Earth's natural systems to counteract climate change or its effects. These interventions aim to either **remove** greenhouse gases from the atmosphere or **reduce** the amount of sunlight reaching the Earth's surface, ultimately making the planet more habitable. However, it currently remains a theoretical concept.

Some proposed methods include deploying parasols, installing mirrors in space, injecting sulfate aerosols into the stratosphere to whiten it, painting building roofs to reflect sunlight, or dispersing iron filings into the ocean to stimulate carbon-absorbing algae. The following are a few examples:

- **Solar Radiation Management (SRM):** SRM methods aim to reflect a portion of sunlight away from the Earth, reducing the amount of solar radiation absorbed by the planet's surface. Examples include:
  - **Stratospheric Aerosol Injection- Mimicking Volcanic Eruptions:** Some scientists suggest injecting sulfur or hydrogen sulfide into the atmosphere to mimic the cooling effect of volcanic eruptions. These substances scatter sunlight back into space, potentially cooling the planet without significantly heating the stratosphere.
  - **Cirrus Cloud Thinning:** Introducing ice nuclei, such as dust particles, into areas containing cirrus clouds enhances the growth of ice crystals, effectively decreasing the optical density of the cirrus clouds. This process thins the clouds, facilitating increased heat dissipation into space, thus promoting planetary cooling.
  - **Marine Cloud Brightening:** Spraying sea salt particles into marine clouds to increase their reflectivity and enhance their ability to reflect sunlight.
  - **Deploying Space Mirrors:** Geo-engineers plan to launch a mirror the size of Greenland into space and position it strategically between Earth and the sun to deflect enough sunlight and restore the climate to pre-industrial levels.
- **Carbon Dioxide Removal (CDR):** CDR methods aim to remove carbon dioxide from the atmosphere and store it elsewhere. Examples include:
  - **Afforestation and Reforestation:** Planting trees on a large scale to absorb carbon dioxide from the atmosphere and store it in biomass.
  - **Direct Air Capture (DAC):** Harnessing chemical wizardry to pluck carbon dioxide molecules straight from the air, whisking them away for underground sequestration or transformation into newfound usefulness.
  - **Developing Artificial Trees:** An "artificial tree" prototype captures a ton of carbon from the atmosphere daily. Panels, coated with an absorbent resin, react with airborne carbon dioxide to form a solid, akin to a furnace filter. These panels are removable and can be cleaned with steam, releasing the captured carbon in liquid form.
  - **Seeding the Ocean with Iron or Nitrogen:** Scientists propose that iron could stimulate phytoplankton growth, as they absorb carbon during photosynthesis. When phytoplankton die, the carbon they've consumed sinks to the ocean floor, potentially reversing global warming. This could be achieved by introducing iron into the sea to promote phytoplankton growth. This phenomenon is usually referred to as **"Ocean Fertilisation."**

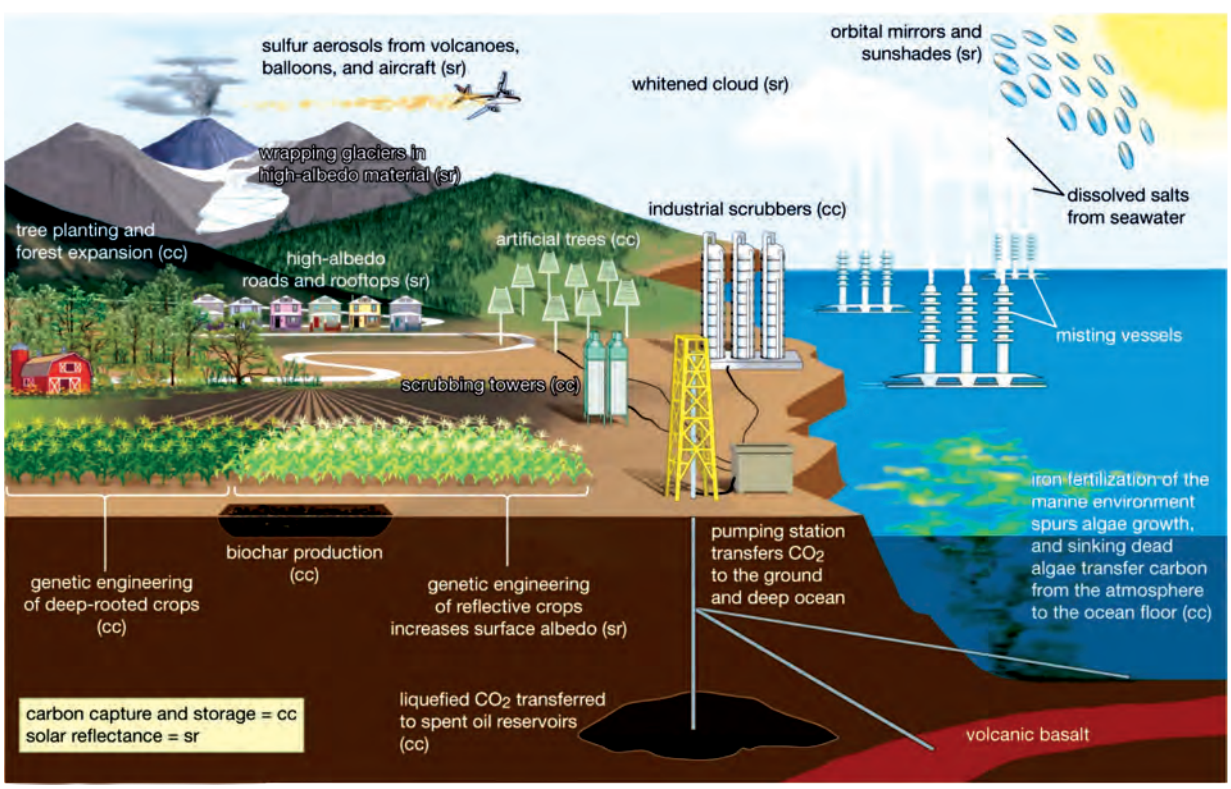

sulfur aerosols from volcanoes, balloons, and aircraft (sr)
orbital mirrors and sunshades (sr)
whitened cloud (sr)
wrapping glaciers in high-albedo material (sr)
dissolved salts from seawater
industrial scrubbers (cc)
tree planting and forest expansion (cc)
artificial trees (cc)
high-albedo roads and rooftops (sr)
misting vessels
scrubbing towers (cc)
iron fertilization of the marine environment spurs algae growth, and sinking dead algae transfer carbon from the atmosphere to the ocean floor (cc)
biochar production (cc)
pumping station transfers CO_2 to the ground and deep ocean
genetic engineering of deep-rooted crops (cc)
genetic engineering of reflective crops increases surface albedo (sr)
carbon capture and storage = cc
solar reflectance = sr
liquefied CO_2 transferred to spent oil reservoirs (cc)
volcanic basalt

Fig 12.6: Carbon Capture and Storage and Carbon dioxide Removal

Challenges and Ethical Concerns with Geo-Engineering

- **Scientific Uncertainty:** Geoengineering techniques involve poorly understood Earth systems, risking unintended consequences with large-scale interventions.
- **Environmental Risks:** Interventions may disrupt ecosystems, alter precipitation patterns, and affect biodiversity, potentially outweighing intended benefits.
- **Governance and Regulation:** Lack of international oversight could lead to unilateral actions, and may heighten geo-political tensions.
- **Moral Hazard:** Reliance on geoengineering may reduce motivation for emissions reduction efforts, creating a moral hazard.
- **Unintended Consequences:** Interventions could have irreversible effects, such as masking warming without addressing root causes.
- **Ethical Considerations:** Geoengineering raises ethical concerns about human intervention in natural systems and moral responsibilities to address climate change sustainably.

Way Forward: A globally negotiated agreement should mandate state-to-state disclosure, empowering countries to make informed decisions regarding geoengineering.

- Scientists could establish a shared repository of geoengineering data, ensuring research is not siloed and benefiting global understanding.
- Solar geoengineering, while not reducing carbon emissions, acknowledges the possibility that reduction strategies may fall short.
- However, relying on this approach poses uncertain consequences, essentially entrusting our planet's fate to an unpredictable **"carbon-sucking fairy godmother."**

Addressing these challenges and ethical concerns requires careful consideration, robust governance mechanisms, and transparent, inclusive decision-making processes involving scientists, policymakers, and affected communities.

IGNITE YOUR MIND

Geoengineering Gamble: You've been recruited for a top-secret mission - to manipulate Earth's climate on a grand scale using untested technologies. Weigh the potential benefits and risks of geoengineering. Is it a gamble worth taking, or a recipe for disaster?

Biofuels

Biofuels are renewable fuels derived from organic materials such as plants, algae, or waste biomass. They have gained attention as a potential tool for climate mitigation due to their ability to reduce greenhouse gas emissions compared to fossil fuels. However, several challenges, concerns, and potentials surround their use:

Types of Biofuels

Biofuels are classified into different types based on their sources and production methods. Here are some common types:

- **First-Generation Biofuels:** These are produced from edible crops such as corn, sugarcane, and vegetable oils. Examples include biodiesel and ethanol.
- **Second-Generation Biofuels:** These are produced from non-edible feedstocks, including agricultural residues, woody biomass and algae non-food crops. They offer improved sustainability compared to first-generation biofuels.

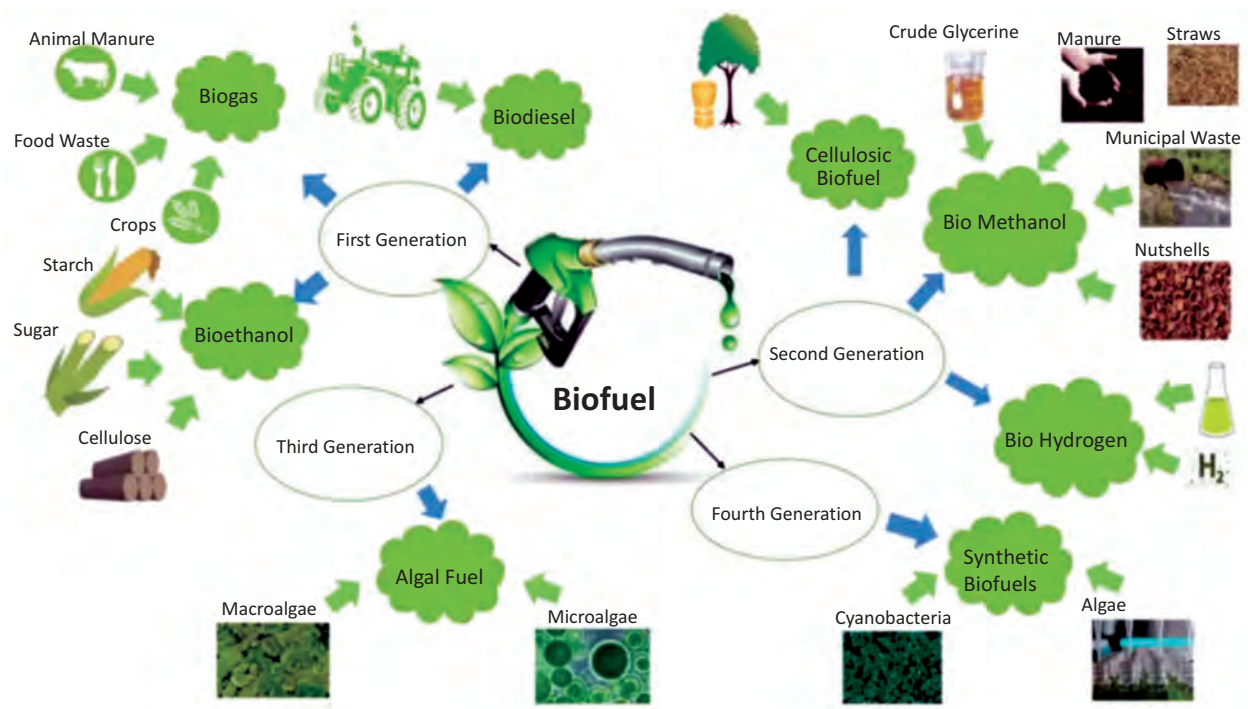


Fig 12.7: Types of Biofuels

- **Third-Generation Biofuels:** Also known as advanced biofuels, these are derived from feedstocks specifically grown for fuel production, such as certain types of algae and other microorganisms.
- **Fourth-Generation Biofuels:** These are formed by breakthrough techniques like Pyrolysis, Gasification or Engineered Algae.

Potential

- **Carbon Sequestration:** Certain biofuel feedstocks, such as perennial grasses and trees, have the potential to sequester carbon in soils and biomass, contributing to climate change mitigation.
- **Renewable Energy Source:** Biofuels offer a renewable alternative to fossil fuels, reducing dependence on finite and environmentally harmful resources.
- **Rural Development:** Biofuel production can provide economic opportunities for rural communities, including job creation and income generation, particularly in agricultural regions.
- **Technological Innovation:** Advances in biofuel production technologies, such as genetic engineering and bioprocessing, have the potential to improve efficiency, reduce costs, and expand feedstock options.
- **Integration with Waste Management:** Biofuels can be produced from organic waste streams, such as agricultural residues, food waste, and municipal solid waste, providing a sustainable solution for waste management while producing renewable energy.

Aspects	Advantages	Disadvantages
Cost	It is made from renewable resources.	Currently more expensive than fossil diesel fuel
Energy availability	Fossil diesel fuel is a limited resource, but biofuels can be manufactured from a wide range of materials	Mainly produced from edible oil, which could cause shortages of food supply and increased prices
GHG emission	Significantly less harmful carbon (CO_2*, CO, THC) emission	Reduction of fuel economy
Energy security	Viability of the first generation biofuel production	Conflicts with food supply
Usage	Relatively less flammable compared to fossil diesel	Less suitable for use in low temperatures
	Significantly better lubricating properties	It can only be used in diesel powered engines
	Significantly less harmful carbon emission compared to standard diesel	More likely than fossil diesel to attract moisture
Air pollution	Significant reduction of PM emissions	Caused increases in NOx
* – different views exist on reduction or increasing of CO_2 emission.		

Challenges

- **Land Use Change:** The cultivation of biofuel feedstocks can lead to land use changes, including deforestation, which can result in increased carbon emissions and biodiversity loss.
- **Food vs. Fuel Debate:** The use of crops for biofuel production may compete with food production, leading to concerns about food security, increased food prices, and land conflicts.
- **Carbon Emissions:** While biofuels are considered carbon-neutral over their lifecycle, the production process, including land conversion and fertilizer use, can still result in carbon emissions, particularly if not managed sustainably.
- **Limited Feedstock Availability:** Scaling up biofuel production may face limitations due to the availability of suitable feedstocks and competition with other uses, such as food, feed, and materials.

Way Forward: Encouraging biofuel adoption in transportation, particularly in nations like India, can curb crude import expenses.

- Biofuels present opportunities for rural and agricultural growth by introducing new cash crops. The focus should be on sustainable biofuel production, utilizing wastelands and urban-generated municipal waste.
- A well-planned biofuel strategy can address both energy needs and food security concerns. Exploring community-driven biodiesel distribution initiatives can foster local economies, benefiting farmers, businesses, and consumers alike.
- **PM JI-VAN Yojana:** The JI-VAN (Jaiv Indhan- Vatavaran Anukool fasal awashesh Nivaran) Yojana, introduced in March 2019, aims to offer financial backing to **integrated bio-ethanol** projects for establishing Second Generation (**2G**) ethanol projects utilizing lignocellulosic biomass and other renewable feedstocks. It falls under the purview of the Ministry of Petroleum and Natural Gas.

Overall, the successful deployment of biofuels for climate mitigation requires addressing the challenges and concerns through sustainable production practices, policy frameworks, and technological innovation. Additionally, biofuels should be part of a broader portfolio of climate mitigation strategies that prioritize emissions reduction, renewable energy deployment and ecosystem protection.

IGNITE YOUR MIND

Biofuel Bonanza or Bust: Biofuels promise a clean energy future, but concerns about land use and sustainability cloud their potential. Can biofuels be harnessed responsibly, or are they simply a greenwashing facade?

Effective climate mitigation necessitates a combination of these strategies, tailored to regional contexts and informed by scientific understanding, social equity, and ethical principles. Collaboration among governments, businesses, communities, and individuals is essential to implement and scale up these solutions, ensuring a sustainable and resilient future for generations to come.

LATEST CLIMATE CHANGE MITIGATION TECHNOLOGIES

Here is a list of some of the latest and most promising climate change mitigation technologies, along with brief descriptions:

Advanced Renewable Energy Systems

- **Floating Offshore Wind Farms:** These wind farms are constructed on platforms situated in deep water, tapping into stronger and more reliable wind resources compared to onshore installations.
  - According to an assessment conducted by the **National Institute of Wind Energy** (NIWE), there is an estimated offshore wind energy potential of 36 GW off the coast of Gujarat and nearly 35 GW off the coast of Tamil Nadu in India.
- **Concentrated solar power (CSP) with thermal storage:** CSP plants utilize mirrors to concentrate sunlight and produce heat, enabling the storage of thermal energy for electricity generation during periods of low solar radiation.
- **Innovative geothermal technologies:** Enhanced Geothermal systems (EGS) employ stimulation techniques to unleash the potential of geothermal energy in regions with lower natural heat gradients.

Negative Emissions Technologies (NETs)

- **Bioenergy with Carbon Capture and Storage (BECCS):** This approach integrates biomass energy generation with CCS, aiming to achieve negative emissions by extracting CO_2 from the atmosphere. This extracted CO_2 can be used for oil recovery.
  - For example, India has recently commenced a project for carbon dioxide-based enhanced oil recovery **(CO_2-EOR)** in the mature oil wells located in western India.
- **Afforestation and Reforestation:** The process of planting trees helps sequester CO_2 from the atmosphere, storing it within the biomass.

Energy Efficiency and Smart Grid Technologies

- **Advanced building materials and designs:** These innovations enhance building insulation and energy efficiency, thereby lowering energy requirements for heating and cooling.
- **Smart grids:** These sophisticated grids streamline energy distribution and usage, minimizing wastage and effectively integrating renewable energy sources.
- **Electric vehicles (EVs):** Transitioning from conventional fossil fuel vehicles to EVs markedly decreases greenhouse gas emissions associated with transportation.

Sustainable Agriculture and Land Management Practices

- **Regenerative agriculture:** This method emphasizes enhancing soil health, biodiversity, and carbon sequestration through techniques like cover cropping and reduced tillage.
- **Precision Agriculture:** Incorporating technology to optimize resource utilization in farming, including fertilizers and water, helps minimize environmental harm.
- **Forestry Management:** Implementing sustainable forest management strategies enhances carbon sequestration and addresses deforestation, a significant driver of climate change.

It is crucial to recognize that these technologies are in different phases of development and adoption. While some are already accessible in the market, others are still undergoing research and development. Furthermore, effectively implementing these technologies necessitates addressing economic, social, and policy factors in addition to technological progress.

INTERNATIONAL EFFORTS FOR CLIMATE CHANGE MITIGATION

International Coalitions

- **International Solar Alliance (ISA):** The International Solar Alliance (ISA) serves as an action-oriented, member-driven collaboration platform aimed at expanding the deployment of solar energy technologies.
  - The **formal name** of the International Solar Alliance is the International Agency for Solar Policy and Application (**IASPA**), with its **secretariat** established at the National Institute of Solar Energy in **Gurgaon**.
  - Its **Mission** is"Every home, no matter how far away, will have a light at home."

- Its **Vision** is "Let us together make the sun brighter."
- Its **fundamental goals** include enhancing energy access, ensuring energy security, and facilitating the transition to renewable energy among its member nations.

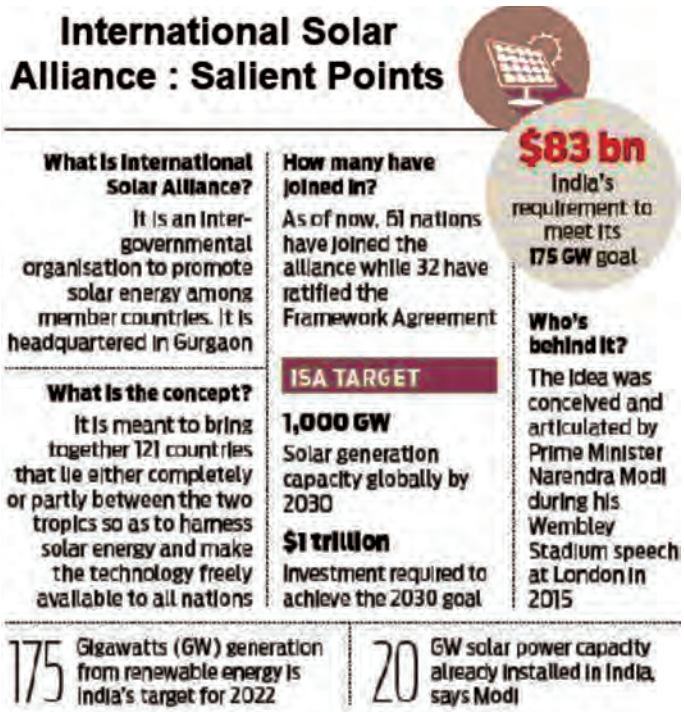

International Solar Alliance : Salient Points
What is International Solar Alliance?
It is an inter-governmental organisation to promote solar energy among member countries. It is headquartered in Gurgaon
What is the concept?
It is meant to bring together 121 countries that lie either completely or partly between the two tropics so as to harness solar energy and make the technology freely available to all nations
How many have joined in?
As of now, 51 nations have joined the alliance while 32 have ratified the Framework Agreement
ISA TARGET
1,000 GW
Solar generation capacity globally by 2030
$1 trillion
Investment required to achieve the 2030 goal
$83 bn
India's requirement to meet its 175 GW goal
Who's behind it?
The idea was conceived and articulated by Prime Minister Narendra Modi during his Wembley Stadium speech at London in 2015
175
Gigawatts (GW) generation from renewable energy is India's target for 2022
20
GW solar power capacity already installed in India, says Modi

Fig 12.8: Salient Points of the International Solar Alliance

- Conceived as a joint initiative by **India and France**, the ISA mobilizes efforts against climate change through the widespread adoption of solar energy solutions.
- It serves as a unique platform for mutual cooperation among **121 countries** endowed with solar resources, situated **fully or partially between the Tropic of Cancer and the Tropic of Capricorn**. The alliance is committed to addressing the specific energy requirements of its member nations.
- Over 110 countries have signed the ISA Framework Agreement, with nearly 100 countries having both signed and ratified it.
- **Eligibility: All United Nations member** states are eligible to join the ISA.
- The United Nations General Assembly (UNGA) has conferred **Observer Status** upon the ISA, enabling organized collaboration between the Alliance and the United Nations to advance worldwide energy expansion and progress.
- The **objectives** of the ISA include driving down prices by stimulating demand, standardizing solar technologies, and promoting research and development in the field.
- The ISA aims to create and implement affordable and revolutionary solar energy solutions.
- Its aim is to aid member nations in shaping low-carbon development trajectories, with a focus on making substantial strides in countries categorized as Least Developed Countries (LDCs) and Small Island Developing States (SIDS).
- Prime Minister Modi introduced the term "**Surya Putra**" to refer to all nations situated between the Tropic of Cancer and the Tropic of Capricorn, inviting them to join the alliance. These countries are also referred to as "**Sunshine Countries**."
- India has launched the IESS 2047 calculator, which stands for **India Energy Security Scenarios 2047**, aimed at exploring potential future energy scenarios for the nation.

PM Modi's 10-point action plan to promote solar power
Prime Minister Narendra Modi on Sunday listed out 10 action points at the founding conference of the International Solar Alliance, to bring about a solar revolution worldwide. They include:
Ensuring that cheap and improved solar technology is easily available
Increasing the percentage of solar energy in countries' national energy mix
Encouraging innovation for development of solutions to problems/challenges
Ensuring concessional and risk-free funding for solar projects
Developing regulatory aspects and norms to speed up adoption of solar technologies, solutions
Consultancy support for bankable solar projects in developing nations
Ensuring efforts to propagate solar revolution stress on partnerships and assimilation
Ensuring creation of a network of centres of excellence that takes into account local circumstances and factors
Ensuring solar energy policies are seen in the context of development that will help in achieving Sustainable Development Goals.
Making the ISA secretariat a strong and professional body

Fig 12.9: 10-Point Action plan to promote Solar power

❑ **Green Grids Initiative —One Sun One World One Grid (GGI-OSOWOG):** GGI-OSOWOG, conceived in 2018, aims to establish global interconnected solar energy systems. This initiative, **under** the International Solar Alliance (**ISA**), is a collaboration between India, the U.K., and Australia, with participation from small island nations like Fiji, Jamaica and Mauritius.

Objectives:

- The vision behind OSOWOG is '**The Sun Never Sets**,' emphasizing the constant presence of sunlight globally.
- By 2030, the initiative aims to create a framework for global cooperation in utilizing renewable resources efficiently and ensuring clean energy access worldwide.
- It seeks to **accelerate** the **transition** to renewable energy by harnessing solar power and establishing a global interconnected electricity grid connecting over 80 countries.
- **Stages of Grid Connection:** The initiative's implementation involves a. connecting Indian grids with the Middle East, South Asia, Southeast Asia, and b. subsequently with the African power grid, c.leading to global interconnectivity.
- **Importance of GGI OSOWOG:** GGI OSOWOG will foster technical, financial, and research cooperation, accelerating the construction of global infrastructure for clean energy. It will facilitate the growth of regional and global renewable energy management centers in India. Additionally, it will drive economic benefits, job creation, poverty alleviation, and address socio-economic challenges.

Challenges & Opportunities: Challenges include the efficiency of existing solar infrastructure, dust deposition on panels and waste management. However, GGI OSOWOG presents opportunities for transforming India's energy system, enhancing rural livelihoods through solar-powered initiatives, and mitigating environmental impacts.

Way Forward: Overcoming challenges requires addressing environmental costs, efficiency issues and waste management. India must carefully weigh costs and benefits, tailor initiatives to its requirements, and focus on institution building. ISA can play a crucial role as an independent institution in decision-making and conflict resolution for multi-country grid projects.

❑ **Coalition for Disaster Resilient Infrastructure (CDRI):** The CDRI represents a joint effort involving governments, United Nations bodies, multilateral development institutions, private sector entities, and academic organizations, united by a common objective to bolster the resilience of infrastructure systems against climate and disaster threats, thus promoting sustainable development.

- Debuting in 2019 during the **United Nations Climate Action Summit** in **New York**, the CDRI stands as India's subsequent prominent global endeavor after the International Solar Alliance, underscoring the nation's role in climate change leadership and fortifying resilience against disasters.
- **Thematic Focus:** CDRI spans across governance and policy, risk evaluation, standards and accreditation, skill enhancement, innovation, post-disaster recovery, financing, and community-centered strategies.

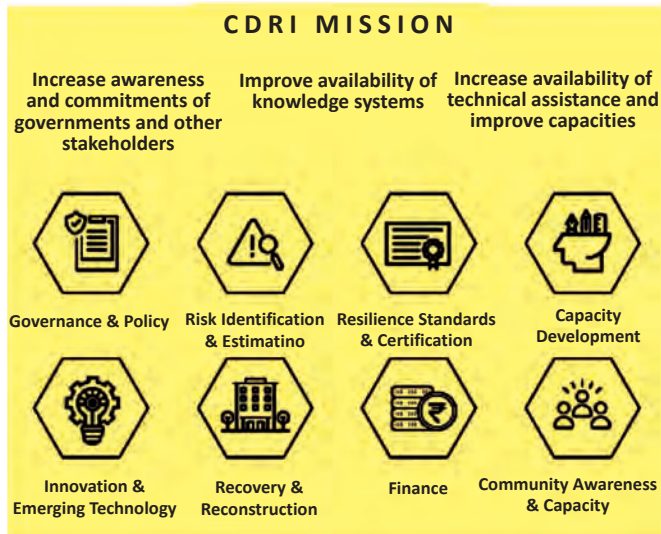

CDRI MISSION
Increase awareness and commitments of governments and other stakeholders
Improve availability of knowledge systems
Increase availability of technical assistance and improve capacities
Governance & Policy
Risk Identification & Estimatino
Resilience Standards & Certification
Capacity Development
Innovation & Emerging Technology
Recovery & Reconstruction
Finance
Community Awareness & Capacity

Fig 12.11: The CDRI Mission

- **Location:** New Delhi, India.
- **Membership:** CDRI boasts 39 national members, six global organizations, and a private sector coalition dedicated to resilient societies.
- **Rationale for CDRI:** The initiative responds to the urgent call outlined in the **Sendai Framework for Disaster Risk Reduction (SFDRR)** to bolster infrastructure resilience, essential for advancing sustainable development objectives and mitigating disaster-induced losses.
- With global infrastructure investment needs estimated at **USD 3.7 trillion per year until 2040**, CDRI plays a vital role in advocating for resilient infrastructure investment to safeguard against future disasters.
- **Significance for India:** For India, CDRI serves as a platform to bolster its leadership in climate action and disaster resilience, enhancing soft power and facilitating sustainable and inclusive growth aligned with the Sustainable Development Goals and climate agreements.
  - Additionally, CDRI complements the objectives of the International Solar Alliance and enables India to extend support for resilient infrastructure development globally, particularly in Africa and Asia.

- Moreover, it offers valuable pathways for infrastructure developers to access knowledge, technology, and capacity-building opportunities, while also providing avenues for Indian infrastructure and technology companies to broaden their international service offerings.

- **Infrastructure for Resilient Island States (IRIS): India** has launched the Infrastructure for Resilient Island States (IRIS) initiative aimed at enhancing the infrastructure of small island nations vulnerable to climate change.
  - This collaborative effort involving India, the U.K., and Australia, with the participation of leaders from small island nations like Fiji, Jamaica, and Mauritius, underscores the global commitment to address climate-related challenges.
  - **Implemented** as part of the Coalition for Disaster Resilient Infrastructure **(CDRI)**, the **IRIS** initiative focuses on capacity building and implementing pilot projects, particularly in small island developing states.
  - The imperative for such an initiative arises from the stark reality that climate change affects nations worldwide, irrespective of their level of development or natural resource wealth.
  - However, Small Island Developing States **(SIDS)** are **disproportionately vulnerable** to its impacts.
  - With one-third of their population residing on lands less than five metres above sea level, SIDS face heightened risks from sea-level rise, storm surges, and coastal erosion.
  - Despite contributing **only 1 percent of global greenhouse gas emissions, SIDS** bear the brunt of climate change consequences.
  - Their agricultural productivity, fisheries, and overall economic sectors are diminishing due to changing climate patterns, jeopardizing livelihoods and economic stability.
  - Additionally, extreme weather events exacerbated by climate change are wreaking havoc on SIDS' land, infrastructure, and economy, exacerbating the challenges they face.

Small Island Developing States (SIDS)

- SIDS constitute a unique group consisting of 38 UN Member States and 20 Non-UN Members/ Associate Members of United Nations regional commissions, each facing distinct social, economic, and environmental vulnerabilities.
- The recognition of SIDS as a distinctive category of developing nations dates back to June 1992, during the UN Conference on Environment and Development.
- **"The Future We Want,"** adopted at the United Nations Conference on Sustainable Development (Rio+20) held in **Rio de Janeiro, Brazil in June 2012,** underscores the particular vulnerabilities of SIDS.
- Geographically, SIDS are situated in three main regions: the Caribbean, the Pacific and the AIS (Atlantic, Indian Ocean, and South China Sea).
- **The Barbados Programme of Action**, formulated in 1994, aims to support SIDS in their endeavors toward sustainable development.
- **Representing this group** of states is the United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries, and Small Island Developing States **(UN-OHRLLS).**

- **The Leadership Group for Industry Transition (LeadIT):** The LeadIT initiative is dedicated to addressing hard-to-abate sectors critical to global climate action, requiring targeted interventions. It brings together nations and businesses committed to fulfilling the objectives of the Paris Agreement.
  - **Launch:** LeadIT was officially established by the governments of **Sweden and India** at the UN Climate Action Summit in 2019, with support from the **World Economic Forum.**
  - **Goals:** LeadIT members are committed to guiding energy-intensive industries towards low-carbon pathways, with the overarching objective of achieving **net-zero carbon emissions by 2050**.
  - **Membership:** The initiative boasts a diverse membership of 39 entities, including 18 countries and 21 companies.
  - **Significance and Focus:** Members pledge to provide technical assistance to new entrants and emerging economies. A central focus of LeadIT's agenda is the recognition of the importance of mitigating investment risks in the transition of heavy industries, particularly in emerging and developing nations.

International Frameworks, Conventions, and Treaties

Various interventions at the intergovernmental level have been a regular feature since the 1970s with discussions related to Ozone, global warming and the broader Climate Change. Let us examine them in a chronological sequence.

Difference between convention, protocol and Treaty has been explained in the following table.

Type	Definition
Treaty	An agreement negotiated by parties to reach common ground and prevent further conflict or disagreement. Typically ratified by the lawmaking authority of the signing government.
Convention	An international meeting of representatives from multiple nations resulting in general agreement on procedures or actions to be taken regarding specific topics (e.g., wetlands, endangered species, etc.).
Protocol	An agreement formulated and signed by diplomatic negotiators as the basis for a final convention or treaty. The treaty itself may take years to complete.

- **United Nations Conference on Human Environment (Stockholm conference), 1972:** The inaugural world conference to prioritize environmental concerns, the Stockholm Conference laid the foundation for global environmental action.
  - Attendees endorsed principles for effective environmental management, culminating in the **Stockholm Declaration** and **Action Plan for the Human Environment** and various resolutions.
  - It initiated a discourse between industrialized and developing nations on the relationship between economic growth, pollution and human well-being, particularly in the context of industrialization fallout.
  - The conference marked the first global acknowledgment of the **right to live in a healthy environment as a fundamental human right.**
  - It highlighted human responsibility for environmental degradation and the alteration of ecosystems, emphasizing the need for human action to address these issues.
  - **Disparities between Developed and Developing Nations:** The conference addressed the disproportionate environmental impact of underdeveloped nations and called for measures to reduce their negative influence while recognizing the environmental challenges faced by industrialized countries.
  - **Governmental Action:** Governments were urged to enact and enforce environmental laws, collaborate with other nations, and coordinate with international agencies to combat pollution.
  - **Establishment of UNEP:** The conference led to the establishment of the **United Nations Environment Programme (UNEP)** in December 1972, providing global leadership in environmental preservation and coordination.
  - **Influence on International Conventions:** The Stockholm convention laid the groundwork for subsequent international agreements on environmental protection, such as the Convention on International Trade in Endangered Species **(CITES)** of Wild Flora and Fauna in 1973.
  - **Legislative Action in India:** In response to the Stockholm convention, India passed key legislative acts, including the **Air (Prevention and Control of Pollution) Act, 1981; the Water (Prevention and Control of Pollution) Act, 1974;** and **the Forest Conservation Act, 1980,** to address environmental concerns.

50 Years of Stockholm Conference

In 2022, Stockholm+50 took place in Stockholm, Sweden, commemorating the 50th anniversary of the 1972 United Nations (UN) Conference on the Human Environment, also known as the Stockholm Conference.

- Among the key agenda points for the event was the discussion of strategies for a sustainable recovery from the Covid-19 pandemic, underscoring the imperative to address the pandemic's impacts alongside ongoing environmental and developmental concerns.

Significance of Stockholm,1972

The significance of it cannot be overstated, as it marked the inaugural global gathering focused on environmental issues at a time when such concerns were not yet widely recognized or prioritized by nations worldwide.

- Prior to this landmark event, the United Nations Charter did not explicitly address environmental matters, and the concept of establishing dedicated ministries or departments for the environment within national governments was virtually non-existent.
- However, following the conference, notable changes occurred, with countries like **Norway and Sweden** leading the way by establishing their own **environment ministries**.
- In subsequent years, other nations, including **India in 1985**, followed suit by creating similar governmental bodies to address environmental issues.
- Issues such as **species extinction** and **mercury poisoning**, which were previously overlooked, began to garner significant attention and media coverage, prompting increased public engagement and advocacy.
- **Influence on Sustainable Development:** The Stockholm Declaration influenced the theme of sustainable development at the 1992 Earth Summit.
- **Key Principles Introduced:** It introduced pivotal principles like the **Precautionary Principle** and **Polluter-Pays Principle.**

Many of the principles outlined in the Stockholm Declaration continue to inform and influence environmental policies and actions undertaken globally to this day.

- **Brundtland Report:** The Brundtland Report, titled "**Our Common Future**," was published in **1987** by the World Commission on Environment and Development (**WCED**), chaired by **Gro Harlem Brundtland**, former Prime Minister of Norway.
  - This landmark report coined the term "**sustainable development"** and laid the groundwork for global environmental policy.
  - The report highlighted the interconnectedness of economic development, social equity, and environmental protection, advocating for policies that promote long-term sustainability. It emphasized the need for addressing poverty, population growth, environmental degradation, and resource depletion simultaneously.

Some Salient Features of the Brundtland Report Include

- **Definition of Sustainable Development:** The report defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
- **Interdependence of Environment and Development:** It emphasized the intrinsic link between environmental conservation and economic development, recognizing that environmental degradation undermines future prosperity.
- **Call for Global Cooperation:** The report stressed the importance of international collaboration in addressing global environmental challenges, calling for collective action by governments, businesses, and civil society.
- **Focus on Equity:** It highlighted the importance of equity and social justice in sustainable development, advocating for policies that prioritize the needs of the marginalized and vulnerable populations.
- **Policy Recommendations:** The report proposed various policy recommendations, including promoting renewable energy, sustainable agriculture, conservation of biodiversity, and responsible consumption and production patterns.

Overall, the Brundtland Report catalyzed global efforts towards sustainable development and remains a foundational document in international environmental policy discourse.

- **Conventions for Ozone Protection : Vienna Convention and Montreal Protocol:** The **Vienna Convention** (1985) and the subsequent **Montreal Protocol** (1987) form a pivotal framework for global cooperation in safeguarding the **ozone layer**. This protocol mandates the phase-out of **ozone-depleting substances (ODS)**, leading to substantial reductions and the **ozone layer's recovery**. **India**, a participant since 1992, actively abides by its regulations, notably phasing out **HCFC-141b**. The **Kigali Agreement**, an amendment to the Montreal Protocol, addresses **hydrofluorocarbons (HFCs)** and stands as a legally binding climate treaty, aiming for an 85% reduction below baseline levels by 2045 across **developed and developing nations**. (*Refer Chapter 11 for more details)*
- **United Nations Conference on Environment and Development (UNCED):** The **Earth Summit of 1992**, also known as The United Nations Conference on Environment and Development (UNCED), aimed to integrate environmental concerns into development initiatives. Held at **Rio de Janeiro** in **Brazil,** it raised public awareness about the critical need for sustainable practices.
  - **Commitments and Follow-up:**
    - **Biodiversity Preservation:** 190 countries pledged to significantly reduce biodiversity loss by 2010 at global, regional, and local levels.
    - **Rio+10 and Rio+20**: Follow-up conferences in 2002 and 2012, respectively, continued discussions on sustainable development.
  - **Issues Addressed:**
    - **Toxic Components:** Strategies to curb toxic substances like **lead** in gasoline and **radioactive** waste.
    - **Alternative Energy**: Promotion of renewable energy sources to replace fossil fuels.
    - **Public Transportation:** Encouragement of public transport systems to reduce vehicle emissions and urban congestion.
    - **Air and Water Pollution**: Focus on tackling health issues arising from polluted air and limited water resources.
  - **Resulting Documents:**
    - **Rio Declaration**: Outlined principles for guiding sustainable development efforts.
    - **Agenda 21**: A non-binding action plan by the UN for sustainable development.
    - **Forest Principles:** Non-legally binding guidelines for forest conservation and sustainability.
  - **Landmark Agreements:**
    - **Climate Change Convention:** Led to the Kyoto Protocol and Paris Agreement, addressing global warming.
    - **Rio Convention:** Legally binding agreements including the Convention on Biological Diversity (**UNCBD**), United Nations Convention to Combat Desertification (**UNCCD**) and United nation Framework Convention on Climate Change (**UNFCCC**) were formed.

Agenda 21

- Agenda 21 is a non-binding action plan by the United Nations (UN) focused on sustainable development, stemming from the Earth Summit 1992. The '21' denotes its applicability for the 21st century, aiming for global sustainable development.
- **Evolution:** Since 2015, it has been integrated into the Agenda 2030, which includes the Sustainable Development Goals (SDGs).

United Nations Convention to Combat Desertification (UNCCD)

- The UNCCD, which stands for United Nations Convention to Combat Desertification, was established in 1994 as the **sole legally binding** environment convention that integrates development and environment with sustainable land management.
- It specifically addresses arid, semi-arid, and dry sub-humid areas, known as **drylands**, where some of the most vulnerable ecosystems and communities are located.
- **Drafted in 1994 and effective in 1996** after receiving 50 ratifications, the convention mandates national governments to take measures to combat desertification.
- The convention's **2018-2030 Strategic Framework** is a comprehensive international commitment to achieve **Land Degradation Neutrality (LDN)**, focusing on restoring productivity of degraded land, enhancing livelihoods of dependent communities, and mitigating the impact of droughts on vulnerable populations.
- Emphasizing a bottom-up approach, the UNCCD involves local communities in achieving its goals.
- As **one of the three Rio Conventions**, alongside the Convention on Biological Diversity (**UNCBD**) and the United Nations Framework Convention on Climate Change (**UNFCCC**), the UNCCD collaborates closely with them.
- To raise awareness about desertification, **2006** was declared as the "**International Year of Deserts and Desertification**."
- Notably, India hosted the 14th session of the Conference of Parties (COP-14) of the UNCCD for the first time in September 2019.

Initiatives of UNCCD

- **Peace Forest Initiative:** It was initiated by South Korea during the 14th Conference of the Parties to the UNCCD in New Delhi, India in 2019, aims to foster collaboration among nations for the restoration of degraded land and forests in vulnerable and post-conflict areas, with an emphasis on fostering peace and building trust.
- **International Coalition for Action on Sand and Dust Storms (SDS):** It aims to create a comprehensive SDS source base map to enhance monitoring and response to these storms. SDS impacts around **77% of UNCCD** country Parties, roughly equivalent to 151 countries.
- **Initiative for Sustainability, Stability, and Security (3S):** It was initiated by 14 African nations to tackle migration caused by land degradation. Its objective is to restore land and generate green employment opportunities for migrants and vulnerable populations.
- **Delhi Declaration:** It encompasses commitments on various fronts such as gender equality, health, ecosystem restoration, climate action, private sector involvement, and the Peace Forest Initiative, along with the recovery of five million hectares of degraded land in India.
  - Country parties have collectively pledged to adopt the Sustainable Development Goal target of achieving land degradation neutrality by 2030 as a national priority for action.

United Nations Convention on Biological Diversity (CBD)

- The United Nations Convention on Biological Diversity (UNCBD) is an international treaty dedicated to conserving biological diversity worldwide.
- Also known as the **Biodiversity Convention**, it was opened for signature at the **Earth Summit** in Rio De Janeiro in 1992, representing a significant milestone in sustainable development. This section has been covered in detail in Biodiversity Conservation and Strategy.

United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty aimed at addressing climate change on a global scale. It came into existence as a result of growing concerns about the impacts of human activities on the Earth's climate system.

- The UNFCCC was established during the **United Nations Conference on Environment and Development**, also known as the **Earth Summit**, held in **Rio de Janeiro, Brazil, in 1992**.
- The conference brought together world leaders, policymakers, scientists, and activists to discuss pressing environmental issues, including climate change.

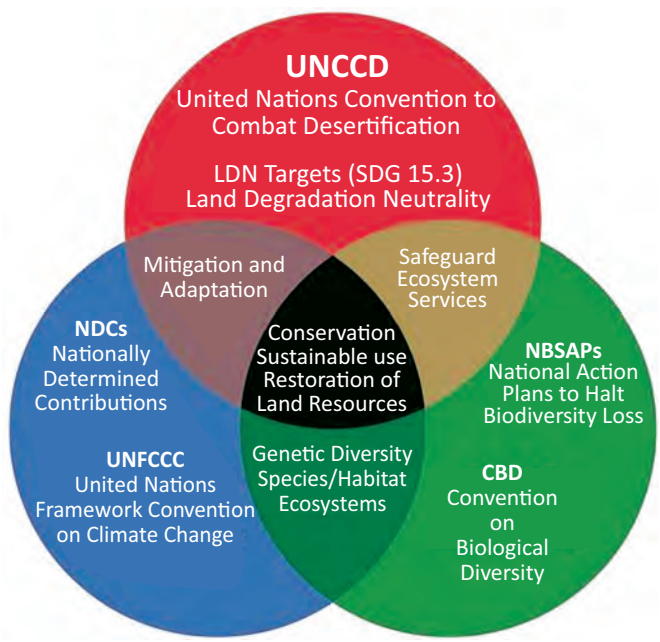


Fig 12.12: Main take-aways from UNCCD COP 15 for ELD

- The UNFCCC was opened for signature at the **Earth Summit** and entered **into force** on March 21, **1994**, after it was ratified by a sufficient number of countries.

- Its **primary objective is to stabilize greenhouse gas concentrations** in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.
- The treaty emphasizes the importance of international cooperation and collective action in addressing climate change, recognizing that it is a global issue that requires a coordinated response from all countries.
- Under the UNFCCC, countries are required to submit national greenhouse gas inventories, adopt policies and measures to mitigate climate change, and provide financial and technological support to developing countries.
- The UNFCCC also serves as the foundation for subsequent international climate agreements, including the Kyoto Protocol and the Paris Agreement, which build upon its principles and commitments to further strengthen global efforts to combat climate change.
- **Rotation based hosting**: The venue for the COP meeting rotates among five regions identified by the UN: Africa, Asia-Pacific, Eastern Europe, Latin America and the Caribbean, and Western Europe and Others.
  - Countries within each region must nominate a candidate, and typically, the host is determined at least two years prior.
  - If no other location is agreed upon, the city of **Bonn** in Germany, where the UNFCCC secretariat is headquartered, is obligated to host the event.

Initiatives of UNFCCC

- **Action for Climate Empowerment (ACE)** It is a term embraced by the UN Framework Convention on Climate Change to encompass efforts outlined in Article 6 of the Convention and Article 12 of the Paris Agreement.
  - The primary objective of ACE is to enable every segment of society to participate in climate action, focusing on six key elements: climate change education and public awareness, training, public participation, access to information, and international cooperation in these areas.
- **Momentum for Change: Climate Neutral Now:** Initiated by the UNFCCC secretariat in 2015, the initiative aims to boost climate action by involving non-Party stakeholders such as sub-national governments, companies, organizations, and individuals.
  - It serves as a platform for raising awareness, building capacity, fostering partnerships, promoting and facilitating the calculation of carbon footprints, reducing emissions, and voluntary offsetting.
- **Gender Action Plan:** At COP22, Parties agreed to establish a "Gender Action Plan" aimed at enhancing women's involvement in climate action. The plan seeks to enable women to have a significant impact on climate change decisions and ensure gender equality in all facets of the UNFCCC.
  - The enhanced gender action plan sets out objectives and activities under five priority areas that aim to advance knowledge and understanding of gender-responsive climate action. The priority areas are mentioned in the figure.
- **Climate Technology Centre and Network (CTCN):** CTCN serves as the operational branch of the United Nations Framework Convention on Climate Change (UNFCCC) Technology Mechanism. Hosted by the United Nations Industrial Development Organization (**UNIDO**) and the United Nations Environment(**UNEP**), it facilitates technology transfer and capacity building for climate action.
  - Its assistance has facilitated projects like establishing a **climate-smart agriculture** platform in **Kenya**, implementing a **waste-to-energy** system in **Nepal**, and launching a **green cooling** initiative in **Ghana**.

Rio+5 (1997)

- A UN General Assembly special session in 1997 evaluated Agenda 21's progress (Rio +5), acknowledging uneven advancements and identifying trends like globalization and environmental deterioration.

Rio+10 (2002) or World Summit on Sustainable Development

- Also known as Earth Summit 2002, it took place in Johannesburg, South Africa, reaffirming the UN's commitment to Agenda 21 and the Millennium Development Goals. The **Johannesburg Declaration** emphasized sustainable development as a global priority.
- The declaration emphasizes addressing global challenges that severely threaten sustainable development, including chronic hunger, malnutrition, armed conflict, natural disasters, terrorism, trafficking in persons, and endemic diseases like HIV/AIDS, malaria, and tuberculosis.

Rio+20 (2012) or United Nations Conference on Sustainable Development

- A conference held in Rio de Janeiro, Brazil, which marked the 20-year anniversary of the Earth Summit in 1992 and the 10-year anniversary of the Earth Summit in 2002. It renewed dedication to Agenda 21 and represented the third global conference on sustainable development.
- This conference aimed to convene governments, international institutions, and major NGO groups to reach consensus on a variety of effective measures for: Alleviating poverty, promoting clean energy and advancing sustainable development

Partnership for Action on Green Economy (PAGE)

The Rio+20 Declaration called for UN support in developing, adopting, and implementing green economy policies and strategies.

- **Goals:** Aims to assist countries in achieving SDG 8 by promoting sustainable economic growth and productive employment.
- **Collaboration:** Involves five UN agencies - UNEP, ILO, UNIDO, UNDP, and UNITAR, pooling expertise to support nations in reframing economic policies around sustainability.

Important COPs and their Outcomes

Here's a summary of the major Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) and their outcomes from COP 1 to COP 25:

- **COP 1 (Berlin, Germany, 1995):** Adoption of the **Berlin Mandate**, setting the stage for negotiations on legally binding emission reduction targets.
- **COP 3 (Kyoto, Japan, 1997)**: Adoption of the **Kyoto Protocol**, establishing legally binding emission reduction targets for developed countries.
- **COP 6 (The Hague, Netherlands, 2000):** Failure to reach an agreement on the implementation of the Kyoto Protocol due to disagreements over emission reduction targets.
- **COP 7 (Marrakech, Morocco, 2001)**: Adoption of the **Marrakesh Accords**, resolving issues left unresolved at COP 6 and establishing rules for implementing the Kyoto Protocol.
- **COP 11 (Montreal, Canada, 2005)**:Adoption of the **Montreal Action Plan,** launching negotiations on future climate action beyond the Kyoto Protocol.
- **COP 15 (Copenhagen, Denmark, 2009):** Failure to reach a legally binding agreement, but the **Copenhagen Accord** was drafted as a political agreement outlining voluntary emission reduction targets.
- **COP 17 (Durban, South Africa, 2011):** Adoption of the **Durban Platform**, launching negotiations on a new legal instrument applicable to all countries to be adopted by 2015.
- **COP 21 (Paris, France, 2015):** Adoption of the Paris Agreement, aiming to limit global warming to well below 2 degrees Celsius above pre-industrial levels, with efforts to limit it to 1.5 degrees Celsius.
- **COP 22 (Marrakech, Morocco, 2016):** Launch of the **Marrakech Partnership for Global Climate Action**, emphasizing cooperation between governments and non-state actors to implement the Paris Agreement.
- **COP 23 (Bonn, Germany, 2017):** Focus on implementing the **Paris Agreement's rulebook** and advancing discussions on climate finance and loss & damage.
- **COP 24 (Katowice, Poland, 2018)**: Adoption of the **Katowice Climate Package,** finalizing the rules for implementing the Paris Agreement and enhancing global climate action.
- **COP 25 (Madrid, Spain, 2019):** Delayed agreement on key issues, including carbon markets, and disappointment over inadequate progress on climate finance and emissions reductions.
- **COP 26 (Glasgow, UK, 2021):** Adoption of the **Glasgow Climate Pact**, with commitments to strengthen emission reduction targets and ramp up climate finance, but criticism over insufficient progress.
- **COP 27 (Sharm El-Sheikh, Egypt, 2022)**: Key outcomes of COP 27 include decisions to establish a fund for addressing **loss and damage**, as well as the initiation of work programs focusing on mitigation, just transition, and climate action in agriculture.
- **COP 28 (Dubai, UAE, 2023):** One significant outcome of COP 28 was the decision regarding the results of the **First Global Stocktake**, aiming to increase global climate ambition by the end of the decade. Additionally, another major outcome was the agreement on operationalizing the Loss and Damage Fund, along with its funding arrangements.

These summaries highlight the major outcomes and developments from each COP, showcasing the evolution of international climate negotiations over the years.

1. Kyoto Protocol

By 1995, it became apparent that the emission reduction provisions outlined in the Convention were insufficient to adequately address climate change. Consequently, negotiations were initiated to bolster the global response to this issue, culminating in the adoption of the Kyoto Protocol two years later.

- The Kyoto Protocol was formally **adopted** in Kyoto, Japan, on 11 December **1997**. However, due to a complex **ratification** process, it did not enter into force until 16 February **2005**.
- In essence, the Kyoto **Protocol serves as the operational framework for the Convention**, **binding** industrialized nations to stabilize their greenhouse gas emissions in accordance with the principles outlined in the Convention.
- One notable **distinction between the Protocol and the Convention** lies in their respective approaches. While the **Convention encouraged** industrialized countries to aim for emission stabilization, the **Protocol mandates** them to do so.
- Regarding targets, the Kyoto Protocol imposes binding emission reduction goals on 37 industrialized countries and the European community during its initial commitment period.
- This **commitment solely applies to developed nations**, acknowledging their historical responsibility for the significant levels of greenhouse gas emissions.
- The fundamental structure of the Kyoto Protocol consists of **three key components** that have been refined and developed over nearly two decades:
  - reporting and verification procedures,

- flexible market-based mechanisms, and
- a compliance system.

Emissions Reduction Commitments

- The initial component involved binding emissions reduction commitments for developed country parties, effectively limiting their pollution allowances.
- Greenhouse gas emissions, particularly carbon dioxide, were now treated as a tradable commodity.
- The Kyoto Protocol began to address the previously unaccounted for **externality of emissions**.

Flexible Market Mechanisms

- The Kyoto Protocol introduced market-based mechanisms centered on emissions permits trading. While countries must primarily meet emission targets domestically, they can also utilize three market-based mechanisms to achieve part of their goals.

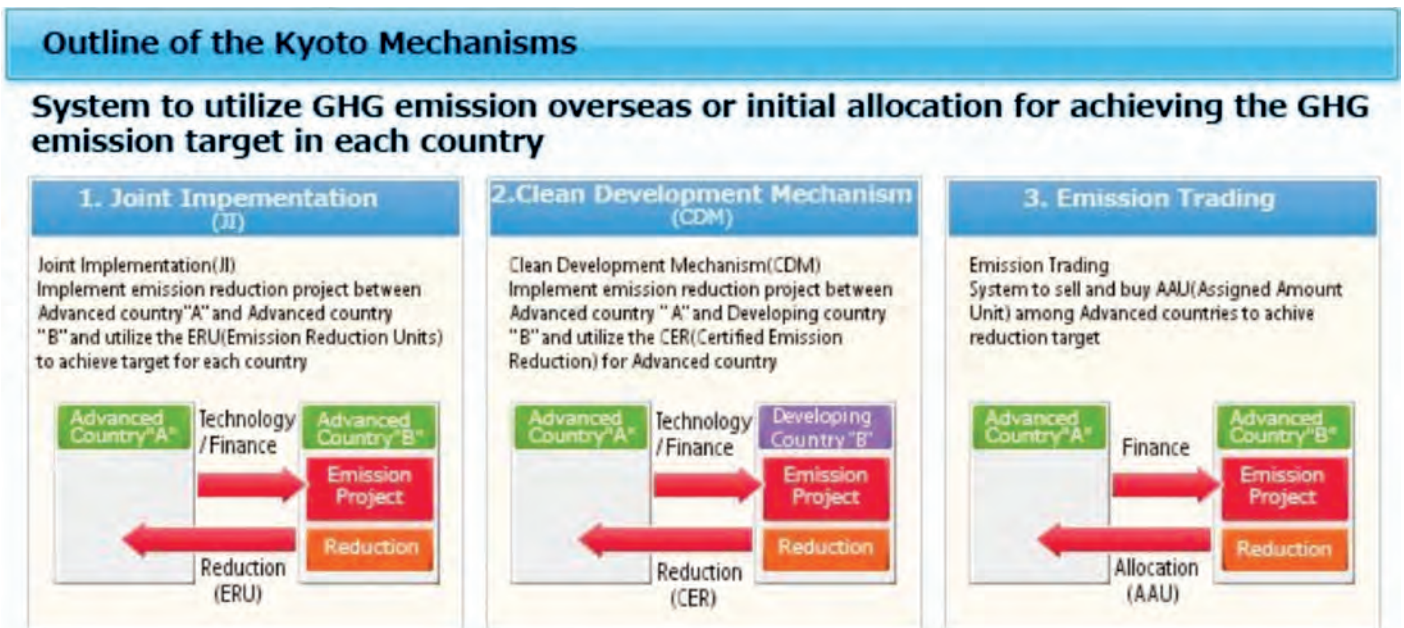

Outline of the Kyoto Mechanisms
System to utilize GHG emission overseas or initial allocation for achieving the GHG emission target in each country
1. Joint Impementation (JI)
Joint Implementation(JI)
Implement emission reduction project between Advanced country"A" and Advanced country "B" and utilize the ERU(Emission Reduction Units) to achieve target for each country
Advanced Country"A"
Technology /Finance
Advanced Country"B"
Emission Project
Reduction
Reduction (ERU)
2.Clean Development Mechanism (CDM)
Clean Development Mechanism(CDM)
Implement emission reduction project between Advanced country "A" and Developing country "B" and utilize the CER(Certified Emission Reduction) for Advanced country
Advanced Country"A"
Technology /Finance
Developing Country"B"
Emission Project
Reduction
Reduction (CER)
3. Emission Trading
Emission Trading
System to sell and buy AAU(Assigned Amount Unit) among Advanced countries to achive reduction target
Advanced Country"A"
Finance
Advanced Country"B"
Emission Project
Reduction
Allocation (AAU)

Fig 12.13: A brief outline of the Kyoto Mechanisms

- These mechanisms encourage greenhouse gas reduction in cost-effective areas, often in developing nations, making emission location less critical as long as they effectively reduce atmospheric pollutants.
- The Kyoto Flexible Market Protocol mechanisms include:
  - Joint Implementation (JI).
  - The Clean Development Mechanism (CDM)
  - Emission Trading
- **The objectives of Kyoto mechanisms are:**
  - Facilitating, promoting, and enforcing compliance with the Protocol's commitments
  - Stimulating sustainable development through technology transfer and investment
  - Assisting countries with Kyoto commitments in meeting their targets by reducing emissions or sequestering carbon in other countries in a cost-effective manner
  - Encouraging contributions from the private sector and developing countries to emission reduction efforts.

Joint Implementation

- The mechanism of "joint implementation" enables a country with emission reduction commitments under the Kyoto Protocol (referred to as an Annex B Party or developed country) to earn emission reduction units (ERUs) from projects that reduce emissions or remove carbon in another Annex B Party.
- Each ERU is equivalent to one tonne of CO_2 and can be used to fulfill the emitting country's Kyoto target.
- Joint implementation provides Parties with a flexible and cost-effective method to meet a portion of their Kyoto obligations, while the host country benefits from foreign investment and technology transfer.

Clean Development Mechanism

- The Clean Development Mechanism (CDM) enables a country with emission reduction commitments under the Kyoto Protocol (referred to as an Annex B Party) to initiate emission reduction projects in developing countries.
- It represents the inaugural global environmental investment and credit mechanism, offering standardized emissions offset instruments known as Certified Emission Reductions (CERs).
- These projects have the potential to generate saleable CER credits, with each CER equivalent to one tonne of CO_2, which can be utilized to fulfill Kyoto targets.

The Kyoto protocol categorizes different countries in various annexures outlining responsibilities of each annexure countries. The same has been listed in the following table.

Annex	Aspect dealt with
Annex 1: Pledge	❑ List of developed countries and economies in transition (EITs), including the US, France, Japan, etc. ❑ These nations committed to lowering their greenhouse gas emissions to 1990 levels by the year 2000.
Annex 2: Give money	❑ Annex II countries are mandated to provide financial aid and technology transfer to developing nations (non-Annex countries) and Economies in Transition (EITs) for climate change mitigation and adaptation efforts. ❑ This subgroup consists of Annex I countries, which include OECD members and the EU, with the exception of EITs such as Russia, which do not contribute financial assistance.
Non Annex: Take money	❑ Developing nations such as India, Brazil, and China are not obligated to adhere to mandatory, binding targets for reducing greenhouse gas emissions, although they are encouraged to consider doing so. ❑ Upon achieving a certain level of development, they may choose to voluntarily join Annex I.
Annex A: GHG Gases	❑ The list enumerates six greenhouse gases that contribute to the overarching issue: Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6).
Annex B:	❑ This mandates Annex I countries (developed nations) to adhere to compulsory, binding targets for reducing greenhouse gas emissions. ❑ For instance, the USA is obligated to reduce its emissions by 7%.
LDC	Special status due to their limited capacities to adapt to effects of CC

Thus, The Kyoto Protocol played a significant role in raising global awareness about climate change and establishing a framework for international cooperation, it faced challenges due to limited participation and lack of binding commitments from major emitters like the United States and China. It laid the foundation for subsequent climate agreements, such as the Paris Agreement in 2015.

2. Paris Agreement (COP21 & its Outcomes)

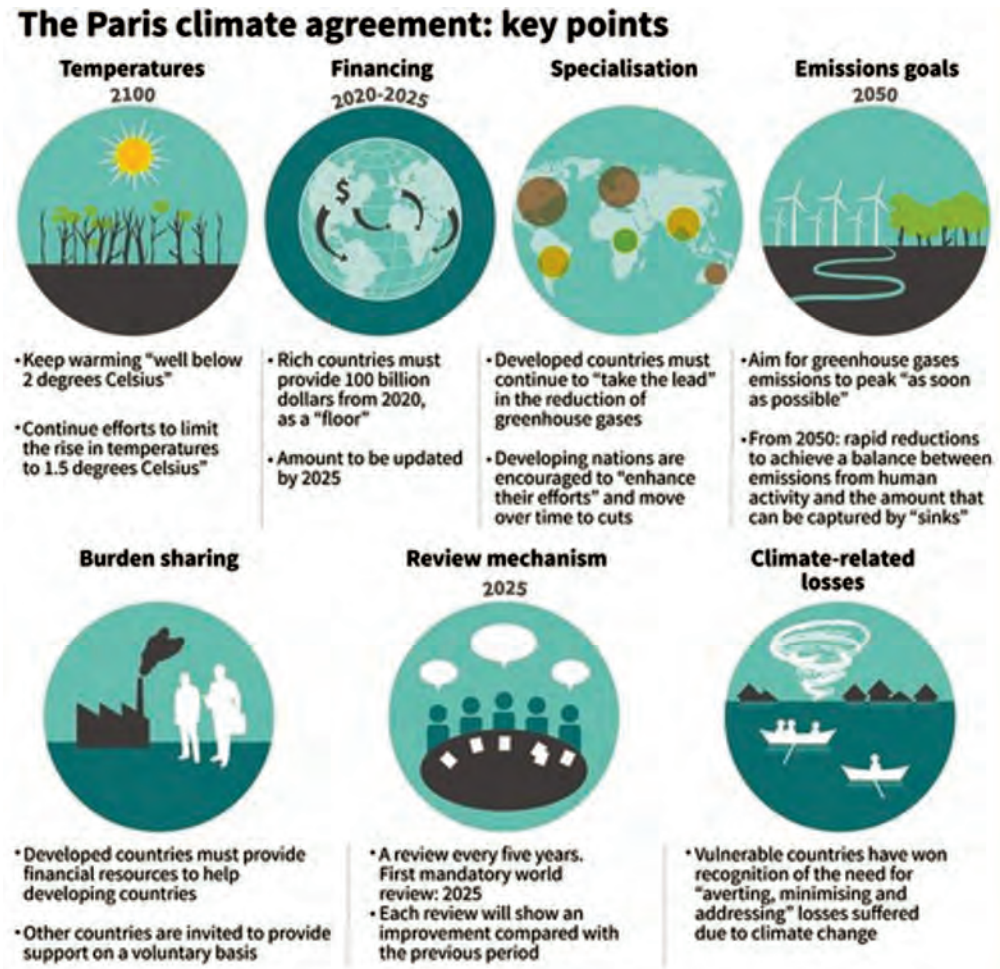

The Paris climate agreement: key points
Temperatures
2100
•Keep warming "well below 2 degrees Celsius"
•Continue efforts to limit the rise in temperatures to 1.5 degrees Celsius"
Financing
2020-2025
$
•Rich countries must provide 100 billion dollars from 2020, as a "floor"
•Amount to be updated by 2025
Specialisation
•Developed countries must continue to "take the lead" in the reduction of greenhouse gases
•Developing nations are encouraged to "enhance their efforts" and move over time to cuts
Emissions goals
2050
•Aim for greenhouse gases emissions to peak "as soon as possible"
•From 2050: rapid reductions to achieve a balance between emissions from human activity and the amount that can be captured by "sinks"
Burden sharing
•Developed countries must provide financial resources to help developing countries
•Other countries are invited to provide support on a voluntary basis
Review mechanism
2025
•A review every five years. First mandatory world review: 2025
•Each review will show an improvement compared with the previous period
Climate-related losses
•Vulnerable countries have won recognition of the need for "averting, minimising and addressing" losses suffered due to climate change

Fig 12.14: Key points of The Paris Agreement

The Paris Agreement, adopted in **2015** during the UNFCCC COP21, is a **legally binding** international accord under the United Nations Framework Convention on Climate Change **(UNFCCC)**. It serves as a **successor to the Kyoto** Protocol, focusing on global efforts to mitigate greenhouse gas emissions, adapt to climate change impacts, and assist developing nations in their climate change endeavors.

Objectives of the Paris Agreement

- To **limit** the increase in global average temperature to **well below 2°C** above pre-industrial levels, with efforts to **limit the increase to 1.5°C**, aiming to mitigate the risks and impacts of climate change.
- To achieve global peaking of greenhouse gas emissions as soon as possible, with a recognition that developing countries may take longer to reach this goal.

Nationally Determined Contributions (NDCs)

- The Paris Agreement mandates all participating countries to submit their NDCs, representing their best efforts to combat climate change, and to enhance these efforts over time. This involves regular reporting on emissions and implementation progress.
- In 2018, countries conducted a review of collective efforts towards the Agreement's goals to inform the preparation of updated NDCs. Additionally, a global stocktake occurs every five years to evaluate progress and guide further action.
- The Paris Agreement came into **effect** on November 4, **2016.** The **first meeting** of the Conference of the Parties serving as the Meeting of the Parties to the Paris Agreement (**CMA 1**) was held in **Marrakech, Morocco**, from November 15-18, 2016.
- By the conclusion of the Marrakech conference, 111 countries had ratified the agreement, representing more than three-quarters of global emissions.
- While the agreement establishes fundamental obligations and mechanisms, the full implementation depends on further elaboration through a comprehensive set of decisions, often referred to as the "**Paris rulebook**," which requires adoption by the participating parties.

3. 26th Conference of the Parties (COP 26) held at Glasgow, UK:

Outcomes of the COP26: Adoption of the **Glasgow Climate Pact**

- **Methane Commitment:**
  - A notable initiative was announced by the European Union and the US to diminish greenhouse gas methane emissions.
  - Participants of this alliance vowed to decrease global methane emissions by 30% from 2020 levels by the year 2030.
  - This commitment holds the promise of averting 0.2 degrees Celsius of global warming.
- **Deforestation Pledge:**
  - More than 100 national leaders pledged to halt and reverse deforestation and land degradation by 2030.
  - The agreement expands on the commitment made by 40 countries in the 2014 New York Declaration of Forests.
- **Resources to support this objective:**
  - **Appeal for Climate Finance:** India advocated for an increase in climate finance to a minimum of USD 1 trillion, surpassing the previous commitment of USD 100 billion made in 2009. India underscored the importance of solidarity and cooperation among Like-Minded Developing Countries (LMDC) during UNFCCC negotiations.
  - **Infrastructure for Resilient Island States (IRIS):** India introduced the IRIS initiative aimed at enhancing the infrastructure of the Small Island Developing States (SIDS) facing substantial climate change threats. The initiative seeks to provide timely information through data systems.
  - **One Sun One World One Grid Group (OSOWOG):** India and the United Kingdom launched the OSOWOG to harness solar energy and facilitate its seamless transmission across borders.
- **India's Commitments in COP26:**
  - **Net-zero Emissions:** India committed to achieving net-zero emissions by 2070, indicating its dedication to long-term climate action.
  - **Non-Fossil Energy Capacity:** India aims to increase its non-fossil energy capacity to 500 GW by 2030, promoting the growth of renewable energy sources.
  - **Carbon Intensity Reduction:** India pledged to reduce its economy's carbon intensity by 45% by 2030, indicating a commitment to sustainable and low-carbon development.
  - **Renewable Energy Adoption:** India aims to fulfill 50% of its energy requirement through renewable energy sources by 2030, contributing to a cleaner energy mix.
  - **Carbon Emissions Reduction:** Reduction of total projected carbon emissions by one billion tonnes from now to 2030.

4. 27th Conference of the Parties (COP 27)

Outcomes of the COP27 held at Egypt's coastal city of Sharm el-Sheikh:

- **Loss and Damage Fund:** Developing nations have long sought financial aid for loss and damage, necessary to rebuild countries ravaged by extreme weather events, for almost three decades. Achieving **consensus on establishing a fund** marks a significant milestone.
  - However, the challenging task remains of setting up and funding the initiative, with ongoing debate about financing sources and mechanisms.

- **Climate Finance Reforms**: Calls for urgent reforms to the World Bank and similar publicly funded finance institutions have gained traction among both developed and developing nations.
  - These institutions have been criticized for **failing** to provide sufficient **funding** to assist **poorer** countries in **reducing greenhouse gas** emissions and adapting to climate change impacts.
  - COP27 discussions extensively addressed potential reforms, including proposals for recapitalizing development banks to enhance support for the developing world.
- **Reaffirmation of Adaptation Commitment:** Enhancing resilience to climate change impacts through measures like flood defenses and ecosystem restoration requires substantial funding, particularly in low-income countries.
  - Despite the **unfulfilled promise of $100 billion** per year in climate finance, with only a fraction allocated to adaptation efforts, COP27 saw a **commitment to double** the proportion of funding for adaptation. Despite challenges, this commitment was ultimately reaffirmed.
- **First High-Level Expert Group Report:** A significant moment at the conference was the unveiling of the inaugural report from the High-Level Expert Group on Non-State Entities' Net-Zero Emissions Commitments.
  - The report scrutinized "**greenwashing**" practices and weak net-zero pledges, offering a roadmap to enhance integrity in industry, financial institutions, cities, and regions' net-zero commitments, promoting a global, equitable transition to sustainability.
- **Launch of Executive Early Warnings for All Initiative:** The UN introduced the Executive Action Plan for the Early Warnings for All initiative during the conference. This initiative advocates for targeted investments totaling $3.1 billion between 2023 and 2027, equivalent to just 50 cents per person annually.
- **Launch of Master Plans for Decarbonization Acceleration:** COP27 featured the introduction of a master plan to expedite decarbonization across five key sectors: power, road transport, steel, hydrogen, and agriculture, led by the Egyptian Presidency.
- **The FAST Initiative:** Egyptian leadership announced the launch of the Food and Agriculture for Sustainable Transformation initiative (FAST) to bolster climate finance contributions, enhancing agriculture and food systems by 2030.
- **Tipping Points and Health:** Following COP26, the IPCC released key findings from its latest climate science assessment, highlighting the urgent need for significant greenhouse gas emissions reductions to avert catastrophic impacts.
  - Notable references were made to tipping points, such as Amazon forest degradation and permafrost thawing, alongside acknowledgment of the right to a clean, healthy, and sustainable environment.

Greenwashing

Greenwashing is a misleading tactic employed by companies or governments to overstate their efforts and effectiveness in addressing climate change, often by presenting misleading information or unsubstantiated claims. This practice aims to exploit the increasing consumer interest in environmentally friendly products.

5. COP28

COP-28 convened in **Dubai, UAE**, featuring representatives from **197** nations who showcased their initiatives to combat global warming and participated in discussions on future climate actions. The conference resulted in a blend of favorable results and setbacks, representing a significant advancement since the Paris Agreement. While some view it as a milestone in ending the fossil fuel era, concerns linger regarding shortcomings in adaptation endeavors and notable gaps in mitigation tactics.

The key highlights of the COP28 Climate Summit include:

- **Emissions Mitigation Targets**:Negotiations will aim to establish ambitious emissions reduction targets, aligning with the Paris Conference's goal of limiting global temperature rise.
- **Phase Down vs Phase-Out:** Developed nations may advocate for an accelerated phase-out, while developing countries, including India, grapple with balancing energy security needs and emission reduction objectives.
- **Climate Finance:** The contentious issue of financial support from developed to developing nations for climate mitigation and adaptation efforts will be addressed. Developing countries require significant funding, estimated at **$200 billion** annually by 2030, to adapt to worsening climate impacts.
- **Industry-led Solutions**: Discussions will center on leveraging industry-led innovations to drive sustainable development and reduce carbon footprints.
- **Low-carbon Innovation:** The conference will emphasize fostering low-carbon innovations and technologies to pave the way for a sustainable future.
- **Progress on Operationalizing the Paris Agreement Article:** Assessment of progress on operationalizing various aspects of the Paris Agreement, including reporting mechanisms and transparency, will be conducted.
- **Reforming the Role of Private Sector Investment:** The role of private sector investment in climate actions will be scrutinized, with a focus on effectively mobilizing private capital to address climate challenges.

India's engagements at COP28:

- **Green Credit Initiative:** Aims to motivate proactive environmental actions by issuing "Green Credits" for planting trees on barren or polluted land and near rivers, ultimately restoring natural ecosystems.

- **Leadership Group for Industry Transition (LeadIT 2.0):** Phase II prioritizes equitable and fair industrial transformation, joint development and sharing of low-carbon technologies, and financial aid for emerging economies transitioning to greener industries.
- **Global River Cities Alliance (GRCA)**: Launched at COP 28, this initiative led by India's National Mission for Clean Ganga underlines the country's commitment to sustainable river management and climate resilience. GRCA serves as a platform for knowledge exchange, pairing river cities, and sharing best practices.
- **Quad Climate Working Group (QCWG) on Localized Climate Action:** This event emphasized the crucial role of local communities and regional authorities in promoting sustainable lifestyles.

Challenges Faced by India at COP28

- **Cooling Pledge:** India is reportedly reluctant to endorse a global commitment to reduce emissions related to cooling at the COP28 climate summit, citing the necessity for affordable cooling in the world's most populous nation.
- **Luxury emissions:** India is urged to decrease "luxury emissions," covering sectors like oil and gas and waste, contributing to Methane Emissions. This request demands a nuanced approach considering its impact on various sectors and India's broader developmental objectives.
- **Loss and Damage Finance:** A recent **CSE-Down to Earth assessment** revealed that India experienced an extreme weather event almost every other day in the first nine months of this year. Hence, India's focus would be on securing "loss and damage finance."
- **Coal dependence and fossil fuel phase-out:** India's reliance on coal for power generation remains contentious. Immediate closure proposals for coal-fired power plants **conflict** with India's emphasis on **energy security.**
- **India's Stance on Emission Reduction:** India refuses to accept any proposal that mandates reducing its emissions. Instead, India frames its climate actions in terms of emissions intensity, or emissions per unit of GDP.
- **Agricultural Emission Cuts and Food Security:** The **agriculture** sector, along with animal husbandry, contributes nearly **15% of India's annual emissions.** Agreeing to emission cuts in agriculture could entail changes in cropping patterns with significant implications for India's food security.
- **Financial support for renewable energy:** As India shifts towards cleaner energy sources, securing financial aid for green energy corridors and grid infrastructure development is crucial. This financial support aligns with the **G20 New Delhi Leader's Declaration**, emphasizing the need for substantial funds.

The COP28 climate summit looms as a watershed moment for global climate action, presenting India with the critical task of balancing emissions reduction with equitable and sustainable development. COP28 stands as a pivotal point for international climate efforts, urging India to chart a course that reconciles emissions reduction with inclusive and sustainable development.

Challenges in Global Efforts Towards Climate Change Mitigation

Addressing climate change mitigation and management poses several challenges across various dimensions like:

- **Political Will and International Cooperation**: Achieving global consensus and cooperation among nations with diverse economic interests and priorities remains challenging.
  - Political commitments may falter due to competing national agendas, lack of leadership, or diplomatic tensions.
- **Economic Impacts:** Transitioning to low-carbon economies requires significant investments in renewable energy, infrastructure upgrades, and sustainable practices.
  - Some countries, especially developing nations, may face economic challenges in funding these transitions and may prioritize short-term economic growth over long-term sustainability.
- **Technological Limitations:** Despite advancements, certain sectors still lack scalable and cost-effective low-carbon technologies.
  - Research and development are crucial to overcome technological barriers and promote innovation in clean energy, carbon capture, and sustainable agriculture.
- **Social Equity:** Climate change disproportionately affects vulnerable populations, exacerbating existing social inequalities.
  - Mitigation and adaptation strategies must address social equity concerns by ensuring marginalized communities have access to resources, adaptation measures, and opportunities for participation in decision-making processes.
- **Behavioral Change**: Encouraging widespread behavioral change and promoting sustainable lifestyles remains a significant challenge.
  - Overcoming inertia and fostering a cultural shift towards climate-conscious behaviors require comprehensive education, awareness campaigns, and incentives for sustainable practices.

- **Global Governance and Legal Frameworks:** The effectiveness of international agreements and frameworks, such as the Paris Agreement, depends on robust governance structures and enforcement mechanisms.
  - Strengthening global governance and legal frameworks is essential to ensure accountability and compliance with climate commitments.
- **Natural Resource Management**: Preserving ecosystems and natural resources is integral to climate change mitigation and adaptation.
  - However, challenges such as deforestation, land degradation, and water scarcity persist, necessitating integrated approaches to conservation and sustainable resource management.
- **Climate Finance:** Mobilizing adequate financial resources for climate action, especially in developing countries, remains a challenge.
  - Access to climate finance, including grants, concessional loans, and private investments, is crucial for implementing adaptation and mitigation projects and building resilience to climate impacts.

Way Forward

- **Integration of Climate Objectives**: Embed ambitious climate goals in national and sub-national development plans and sectoral policies, aligning them with Nationally Determined Contributions (NDCs) and long-term strategies.
- **Strengthening National Climate Leadership:** Enhance climate leadership at the government's core, empowering centralized governance structures to drive and coordinate cross-sectoral climate action.
- **Resourcing Climate Capacity:** Allocate resources to build fundamental climate capacity within government centers to facilitate ambitious cross-sectoral initiatives.
- **Integration in Development Financing:** Integrate climate change into national development financing strategies to leverage broader resources for sustainable development.
- **Incorporating Climate in Budgeting and Tax Systems:** Incorporate climate objectives into national budgeting frameworks and tax systems to incentivize low-emissions, climate-resilient practices.
- **Strengthening Institutional Mandates**:Establish robust institutional mandates aligned with the ambition of the Paris Agreement to drive transformative climate action.
- **Aligning Performance and Incentive Systems**: Implement performance and incentive systems that motivate staff to promote ambitious climate action and provide tools for contributing to climate initiatives.
- **Establishing De-risking Partnerships**: Forge partnerships to de-risk infrastructure financing in developing countries, pooling capacities and resources for systemic impact.

International Plant Protection Convention

The International Plant Protection Convention (IPPC) is an intergovernmental treaty dedicated to safeguarding the world's plants, agricultural products, and natural resources from plant pests. With 185 contracting parties, the IPPC focuses on developing, adopting, and promoting the implementation of International Phytosanitary Measures (ISPMs) as the primary means to ensure global food security, facilitate safe trade, and preserve the environment. Its objectives are:

- Ensuring plant health is vital for global food security, as it helps meet the increasing demand for food in the world.
- Implementing international phytosanitary standards promotes safe trade practices, mitigating the adverse effects of plant pests on the environment, economies, and livelihoods.
- Safeguarding plant health aids in environmental protection by reducing the introduction and spread of invasive species, thereby preserving biodiversity and mitigating the impacts of climate change.

INDIAN EFFORTS IN CLIMATE CHANGE MANAGEMENT

India has progressively intensified its efforts to address climate change, reflecting a growing recognition of the environmental challenges facing the nation. Key milestones in India's climate journey during this period include:

- The **Bhopal Gas Tragedy in 1984**, one of the world's worst industrial disasters, highlighted the need for stringent environmental regulations and safety measures in industrial operations.
- India established key environmental institutions, such as the **Ministry of Environment, Forest, and Climate Change (MoEFCC)** in 1985, to coordinate environmental governance and policy formulation.
- India adopted various national conservation strategies and policies, such as the **National Forest Policy (1988)** and the **National Action Plan on Climate Change (NAPCC)** in 2008, to address environmental degradation and climate change challenges.
- India actively participated in international climate negotiations, including the United Nations Framework Convention on Climate Change (UNFCCC) negotiations leading to the Kyoto Protocol in 1997 and subsequent COP meetings.
- In 2008, it launched the National Adaptation Plan on Climate change. India aligned its climate actions reflected in its commitment to the Paris Agreement 2015. Subsequently, the NDCs submitted in the Paris agreement were updated in 2022.

Jawaharlal Nehru National Solar Mission
Objective: To establish India as a global leader in solar energy
Budget ₹8,795 crore
Key achievements
Installed 2,970 MW of grid-connected solar generation capacity
Installed 364 MW of off-grid solar generation capacity
Installed 8.42 million sq m of solar thermal collectors
National Mission for Enhanced Energy Efficiency
Objective: To achieve growth with ecological sustainability by devising cost-effective, energy-efficient strategies
Budget ₹190 crore
Key achievements
Distributed 2.58 million LED bulbs (7 watts); cost of an LED bulb down from ₹500 to ₹204
Super-efficient ceiling fans to be introduced this year
National Water Mission
Objective: To conserve water, minimise wastage and ensure equal distribution both across and within states through integrated water resources development
Budget ₹89,101 crore
Key achievements
Revised National Water Policy (2012) adopted by National Water Resources Council
Created 1,082 new Ground Water Monitoring Wells
National Mission on Sustainable Habitat
Objective: To promote sustainability of habitats by improving energy-efficiency in urban planning
Budget ₹950 crore
Key achievements
Energy Conservation Building Code 2007 made mandatory for new as well as old buildings
Long-term transport plan for cities prepared
Sanctioned 760 water supply projects
National Mission for Sustainable Agriculture
Objective: To transform agriculture into an ecologically sustainable climate-resilient production system and ensuring food security
Budget ₹1,08,000 crore
Key achievements
Developed 11,000 hectares of degraded land
1 million hectares brought under micro-irrigation to promote water efficiency
Created 5.4 million tonne agricultural storage capacity
National Mission for Sustaining the Himalayan Ecosystem
Objective: To safeguard the Himalayas and attempt to address impacts of climate change on Himalayan glaciers, biodiversity and wildlife conservation
Budget ₹1,695 crore
Key achievements
Established 6 new centres relevant to climate change in existing institutions in Himalayan states
Created an observational network to monitor health of the Himalayan ecosystem
National Mission for a Green India
Objective: To grow and maintain sustainably managed forests and other ecosystems
Budget ₹46,000 crore
Key achievements
11 Indian states have submitted perspective plans that cover 33 landscapes and working area of 85,000 hectares
Finalised implementation norms after extensive consultations with state governments & civil society
National Mission on Strategic Knowledge for Climate Change
Objective: To identify challenges and responses to climate change through research and technology development; ensure funding of high-quality and focused research
Budget ₹2,500 crore
Key achievements
Established 12 thematic knowledge networks
Developed 3 regional climate models
Trained 75 high-quality climate change professionals

Fig 12.16: The National Action Plan on Climate Change

Let us examine some of the Indian initiatives for climate mitigation in detail :

National Action Plan on Climate Change (NAPCC)

The National Action Plan on Climate Change (NAPCC) was initiated in 2008 by the Prime Minister's Council on Climate Change to raise awareness among various stakeholders about the threat of climate change and measures to mitigate it.Comprising **eight national missions**, NAPCC encompasses multi-pronged, long-term strategies aimed at achieving key climate change goals:

- Driven by various principles, the NAPCC prioritizes safeguarding vulnerable segments of society through inclusive and sustainable development that is attuned to climate change.
- Fostering national development through qualitative shifts that prioritize ecological sustainability.
- Rapid and widespread adoption of suitable technologies to address both adaptation to and mitigation of greenhouse gas emissions.
- Advancement of regulatory and voluntary frameworks to stimulate sustainable development and cultivate inventive market structures.

- Efficient execution of strategies through novel collaborations with civil society and local administrations via public-private partnerships.
- Advocacy for global collaboration in research, development, and technology exchange, bolstered by adequate funding and a unified Intellectual Property Rights (IPR) framework under the United Nations Framework Convention on Climate Change (UNFCCC).

The approach of NAPCC: It involves shifting the developmental trajectory towards addressing critical climate change needs and augmenting existing and planned programmes and technologies. It identifies measures that not only advance developmental objectives but also yield co-benefits by addressing climate change.

1. National Solar Mission

The National Solar Mission is a significant initiative by the Government of India and state governments aimed at fostering ecologically sustainable growth while addressing the nation's energy security challenges.

Objectives:

- Establishing India as a global leader in solar energy by creating favorable policy conditions for its widespread adoption across the country.
- Implementing the mission in **three phases**:
  - **Phase 1** covering the remainder of the 11th Plan and the first year of the 12th Plan (up to 2012-13),
  - **Phase 2** spanning the remaining four years of the 12th Plan (2013-17), and
  - **Phase 3** during the 13th Plan (2017-22).

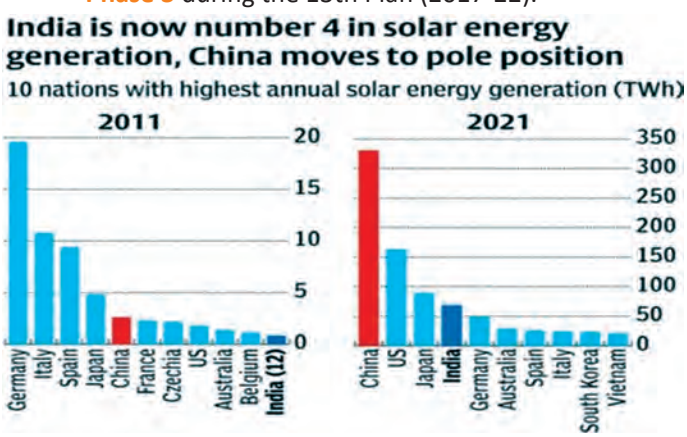


Fig 12.17: Nations with Highest Annual Solar Energy Generation Capacity

- Conducting **periodic evaluations** at the end of each plan period and mid-term reviews during the 12th and 13th Plans to assess progress, review capacity, and set targets for subsequent phases based on emerging cost and technology trends.
- Focusing on capturing low-hanging opportunities in solar thermal technology, promoting **off-grid** systems to serve **energy-deprived populations**, and modestly increasing capacity in grid-based systems during Phase 1.
- Aggressively ramping up capacity during Phase 2 based on experiences from the initial years to facilitate scaled-up and competitive solar energy penetration nationwide.

Mission Targets

- Establishing an enabling policy framework to deploy **100 GW** of solar power by 2022.
- Revising cumulative targets under the National Solar Mission from 20,000 MW by 2021-22 to 100,000 MW, representing a significant increase.
- Primarily comprising **40 GW from rooftop** installations and **60 GW** from large and medium-scale **grid-connected** solar power projects.

2. National Mission for Enhanced Energy Efficiency

The National Mission for Enhanced Energy Efficiency (NMEEE) aims to bolster the energy efficiency market through the establishment of conducive regulatory and policy frameworks. It is under the jurisdiction of the Ministry of Power and the Energy Conservation Act of 2001 forms the basis.

The implementing agencies for NMEEE include the Bureau of Energy Efficiency (BEE) and Energy Efficiency Services Limited (EESL).

Objectives

- NMEEE aims to promote innovative and sustainable business models within the energy efficiency sector. It endeavors to cultivate and sustain energy efficiency markets across the country for the benefit of both the nation and consumers.

Mission Goals

- Introducing market-based approaches to unlock energy efficiency opportunities estimated at approximately Rs. 74,000 crores.
- By 2014-15, achieving annual fuel savings exceeding 23 million toe, cumulative avoided electricity capacity addition of 19,000 MW, and CO_2 emission mitigation of 98 million tons per year.

Other initiatives by BEE and EESL

- **Perform Achieve & Trade (PAT):** Assigning energy reduction targets to large energy intensive industries and distributing Energy Saving Certificates (ESCerts) on achievement of the targets.
- **Market Transformation for Energy Efficiency (MTEE):** Promoting adoption of energy efficient equipment and appliances through innovative business models.
- **Energy Efficiency Financing Platform (EEP):** Catalyzing the finances for the energy efficiency sector by addressing the barriers and challenges in market development and project implementation.
- **Framework for Energy Efficient Economic Development (FEED):** To protect the confidence of banks and investors in energy efficiency projects and to avoid the stalling of projects due to lack of funds.

3. National Mission on Sustainable Habitat

The "National Mission on Sustainable Habitat" aims to enhance the sustainability of habitats through various measures such as improving energy efficiency in buildings, urban planning, better management of solid and liquid waste, promoting modal shift towards public transport, and implementing changes in the legal and regulatory framework to support conservation efforts. The Ministry of Urban Development governs the mission.

Additionally, it aims to enhance the resilience of habitats to climate change by improving infrastructure, community-based disaster management, and enhancing advance warning systems for extreme weather events.

The mission will focus on the following key areas:

- Extension of energy conservation building codes to optimize energy demand in new and large commercial buildings.
- Improvement of urban planning and promotion of public transport to facilitate the growth of medium and small cities, ensuring efficient and convenient public transportation.
- Implementation of recycling initiatives and effective urban waste management, with a special emphasis on developing technology for generating power from waste.
- The National Mission will also include a significant research and development program, concentrating on biochemical conversion, wastewater utilization, sewage management, and recycling options.
- Introduce financial incentives tied to green rating systems.
- Encourage practices that minimize water pumping, enhance wastewater treatment, and improve toilet designs.
- Advocate for the utilization of natural gas and alternative/renewable fuels.
- Propose comprehensive urban renewal master plans integrating sustainable design principles.

4. National Water Mission

Under the governance of the **Ministry of Water Resources, River Development, and Ganga Rejuvenation**, the National Mission on Water aims to achieve better-integrated water resource management, leading to water conservation, reduced wastage, and equitable distribution through improved policy frameworks.

It addresses issues such as groundwater and surface water management, domestic and industrial water use, enhancement of water storage capacities, and preservation of wetlands.

Objectives

- Implementing integrated water resource management strategies to conserve water, minimize wastage, and ensure equitable distribution across and within states.
- Developing a regulatory framework to **enhance water use efficiency by 20%**, based on differential entitlements and pricing, aligned with the **National Water Policy (NWP)**.
- Promoting the recycling of wastewater to fulfill a significant portion of urban water demands.
- Meeting the water needs of coastal cities through the adoption of innovative technologies like low-temperature desalination.
- Reviewing the NWP to incorporate basin-level management strategies to address climate change-induced variability in rainfall and river flows, including measures for rainwater harvesting and enhanced storage.
- Establishing new regulatory mechanisms to optimize the efficiency of existing irrigation systems, rehabilitate degraded systems, and expand irrigation capacity.
- Encouraging the adoption of **water-neutral and water-positive technologies** through incentivization and large-scale irrigation programs focused on efficient irrigation methods and groundwater recharge.
- The establishment of a publicly accessible water database and the evaluation of climate change's influence on water resources.

5. National Mission for Sustaining the Himalayan Ecosystem

The National Mission for Sustaining the Himalayan Ecosystem is overseen by the **Department of Science and Technology**. The primary goal of the mission is to establish a sustainable **national capacity** for continuously monitoring the health of the Himalayan ecosystem. This involves assisting policy-making bodies and aiding states in the Indian Himalayan Region in implementing sustainable development actions.

Mission Objectives:

- Enhancing human and institutional capacities in climate change-related areas.
- Establishing a network of knowledge institutions and developing a comprehensive database on all knowledge systems.
- Identifying and distinguishing between natural and human-induced global environmental changes and forecasting future trends regarding potential impacts.
- Evaluating the socio-economic and ecological effects of global environmental changes and devising suitable strategies for regional economic growth.
- Exploring traditional knowledge systems for community involvement in adaptation, mitigation, and coping mechanisms.
- Assessing policy options for regional development plans.
- Raising awareness among stakeholders in the region.
- Fostering regional cooperation to build a robust knowledge base for policy interventions.

6. National Mission for a Green India

Governed by the **Ministry of Environment, Forest, and Climate Change**, the National Mission for Green India aims to rejuvenate degraded forest land with a primary focus on **increasing forest cover and density** while **conserving biodiversity**. It works towards reducing forest fragmentation, fostering private-public partnerships for plantation initiatives, and enhancing schemes based on joint forestry management. Additionally, the mission develops strategies to address challenges posed by climate change.

Mission Objectives

- Enhance **forest/tree cover** on 5 million hectares of forest/non-forest lands and improve the quality of forest cover on another 5 million hectares of non-forest/forest lands (a total of 10 million hectares).
- Improve **ecosystem services**, including biodiversity, hydrological services, and carbon sequestration, from the 10 million hectares of forest/non-forest lands mentioned above.
- Increase forest-based livelihood income for about 3 million households living in and around forests.
- Enhance annual **CO_2 sequestration** by 50 to 60 million tons by the year 2020.
- Improve the quality of forest cover and ecosystem services of forests/non-forests, including moderately dense, open forests, degraded grasslands, and wetlands (5 million hectares).
- Undertake eco-restoration/afforestation of scrub, shifting cultivation areas, cold deserts, mangroves, ravines, and abandoned mining areas (2 million hectares).
- Improve forest and tree cover in **urban/peri-urban lands** (0.20 million hectares).
- Enhance forest and tree cover on marginal agricultural lands/fallows and other non-forest land under agroforestry/social forestry (3 million hectares).
- Manage public forest/non-forest areas taken up under the mission by community institutions.
- Promote the adoption of improved fuel wood-use efficiency and alternative energy devices by households in the project area.

This mission is crucial for achieving sustainable forestry practices and biodiversity conservation while addressing the impacts of climate change.

7. National Mission for Sustainable Agriculture

Under the purview of the Ministry of Agriculture, the National Mission for Sustainable Agriculture focuses on formulating strategies to enhance the resilience of Indian agriculture in the face of climate change. Its objectives include the identification and development of new crop varieties and the integration of traditional and modern agricultural practices. The mission prioritizes interventions in dryland agriculture, risk management, access to information, and the application of biotechnology.

Mission Objectives

- To develop **strategic plans** tailored to the **agro-climatic zones**, ensuring that action plans are contextualized to regional scales across various domains such as research and development (R&D), technology, infrastructure, and capacity building.
- The aim is to boost agricultural **productivity** through customized interventions, including the use of biotechnology to develop improved crop and livestock varieties, promotion of efficient irrigation systems, demonstration of appropriate technology, and capacity building and skill development.
- To improve access to information and institutional support, initiatives will be undertaken to expand Automatic Weather Station networks to the panchayat level and integrate them with existing insurance mechanisms like the Weather Based Crop Insurance Scheme and the **National Agriculture Insurance Scheme (NAIS)**, thereby enhancing returns at the grassroots level.
- Promotion of "**laboratory to land" research** will involve creating model villages and farm units in rainfed and dryland areas.
- Long-term interventions for emission reduction from energy and non-energy uses will be strategized, including the introduction of suitable crop varieties and farm practices, as well as livestock and manure management.

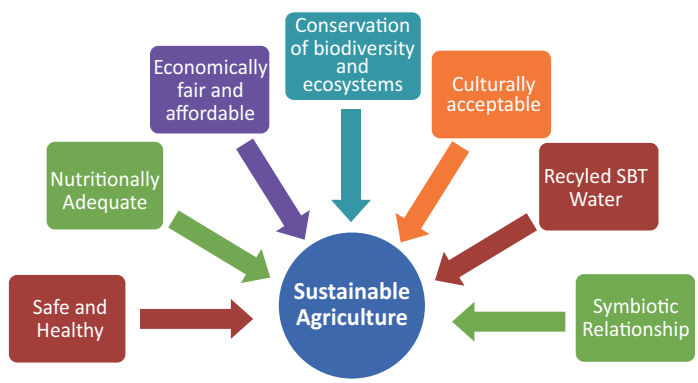


Fig 12.18: Key Dimension of Sustainable Agriculture

- To harness the potential for growth in **dryland agriculture**, efforts will focus on developing drought and pest-resistant crop varieties, adopting resource-conserving technologies, providing institutional support to farmers, and capacity building of stakeholders.

National Mission for Sustainable Agriculture (NMSA) has identified **ten key dimensions** for adaptation and mitigation:

1. Improved Crop Seeds, Livestock, and Fish Culture
2. Water Efficiency
3. Pest Management
4. Improved Farm Practices
5. Nutrient Management
6. Agricultural Insurance
7. Credit Support

8. Markets
9. Access to Information
10. Livelihood Diversification

8. National Mission on Strategic Knowledge for Climate Change

Governed by the **Department of Science and Technology,** the National Mission on Strategic Knowledge for Climate Change aims to address the challenges posed by climate change through international collaboration and adequate research funding. It emphasizes the need for a robust knowledge system on climate change.

Objectives Include

- Establishing **knowledge networks** among research institutions engaged in climate science.Formation of **global technology watch groups** to research risk-minimized technology selection.
- Developing national capacity for modeling climate change impacts on different ecological zones and sectors. Encouraging research on climate change impacts on agriculture, health, ecosystems, biodiversity, and coastal zones.
- Generating knowledge to define sustainable development pathways considering climate change actions.Enhancing understanding of climate processes, risks, and consequences.
- Strengthening **indigenous capacity** for developing technologies for adaptation and mitigation.
  - Building research infrastructure and promoting human resource development in climate science.
  - Forming alliances and partnerships for **global collaboration** in climate change research and technology development.
  - These initiatives aim to advance understanding and response to climate change, ensuring sustainable growth and development.

India's Updated NDCs (Nationally Determined Contributions)

India's Nationally Determined Contribution (NDC) represents its plan to achieve its climate objectives and is in line with the Paris Agreement adopted in 2015. These contributions are submitted every five years to the United Nations Framework Convention on Climate Change (UNFCCC) secretariat.

- In August 2022, India officially revised its NDC, a move that was endorsed by the Union Cabinet. During the 26th session of the Conference of the Parties **(COP26)** to the United Nations Framework Convention on Climate Change (UNFCCC) in **Glasgow, United Kingdom**, India pledged to amplify its climate efforts by unveiling five key elements, referred to as the "**Panchamrit**," of its climate action plan.
- This update to India's existing Nationally Determined Contribution (NDC) reflects the incorporation of the "Panchamrit" initiative announced at COP26 into more ambitious climate targets.
- It also represents a significant stride towards India's overarching objective of achieving net-zero emissions by 2070.

The **2015 NDC** comprised **eight** goals; three of these have **quantitative targets** upto 2030 namely,

1. Cumulative electric power installed capacity from non-fossil sources to reach 40%.
2. Reduce the emissions intensity of GDP by 33 to 35 percent compared to 2005 levels
3. Creation of additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover.

Updated NDCs

- Reducing the emission intensity of its GDP by 45% by 2030, compared to the 2005 level.
- 500 GW of non-fossil fuel installed power generation capacity by 2030.
- Cutting absolute emissions by one billion tonnes, presumably from projected business-as-usual (BAU) 2030 levels.

In addition to the above, two other goals announced as part of the **Panchamrit** are:

- Net Zero emissions – To be achieved by 2070.
- To meet 50% of cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030.

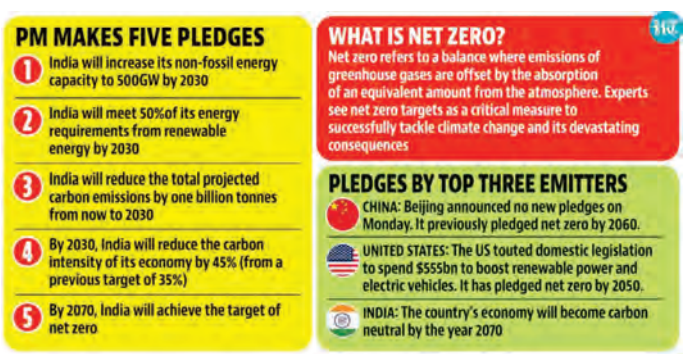

PM MAKES FIVE PLEDGES
1 India will increase its non-fossil energy capacity to 500GW by 2030
2 India will meet 50%of its energy requirements from renewable energy by 2030
3 India will reduce the total projected carbon emissions by one billion tonnes from now to 2030
4 By 2030, India will reduce the carbon intensity of its economy by 45% (from a previous target of 35%)
5 By 2070, India will achieve the target of net zero
WHAT IS NET ZERO?
Net zero refers to a balance where emissions of greenhouse gases are offset by the absorption of an equivalent amount from the atmosphere. Experts see net zero targets as a critical measure to successfully tackle climate change and its devastating consequences
PLEDGES BY TOP THREE EMITTERS
CHINA: Beijing announced no new pledges on Monday. It previously pledged net zero by 2060.
UNITED STATES: The US touted domestic legislation to spend $555bn to boost renewable power and electric vehicles. It has pledged net zero by 2050.
INDIA: The country's economy will become carbon neutral by the year 2070

Fig 12.19: Panchamrit: Five key elements of India's pledge to amplify climate efforts

India's revised Nationally Determined Contribution (NDC) has been formulated with meticulous consideration of our domestic context and the principle of common but differentiated responsibilities and respective capabilities **(CBDR-RC)**.

- It also reiterates India's pledge to pursue a path of low carbon emissions while simultaneously striving to accomplish sustainable development objectives.

- The revised NDC serves as the **blueprint for India's transition towards cleaner energy** from 2021 to 2030. Alongside various government initiatives, such as tax benefits and incentives like the Production Linked Incentive scheme aimed at fostering the manufacturing and adoption of renewable energy, it presents an avenue for bolstering India's manufacturing prowess and augmenting exports.
- This will result in a broader proliferation of green employment opportunities, spanning sectors like renewable energy and clean energy industries—including automotive manufacturing, the production of low-emission products like Electric Vehicles and highly efficient appliances, and the development of innovative technologies such as green hydrogen.

NICRA

The National Initiative on Climate Resilient Agriculture (NICRA) was initiated by the Indian Council of Agricultural Research **(ICAR)** in 2010-2011.

- Its main objective is to enhance the resilience of crops, livestock, and fisheries by developing production and risk management strategies.
- NICRA comprises several project components, including strategic research on adaptation and mitigation, technology demonstration on farmers' fields to address current climate variability, sponsored and competitive research grants to address critical research gaps, and capacity building for various stakeholders.

BSE Greenex

BSE Greenex is the 25th dynamic index hosted on the Bombay Stock Exchange, making it India's first carbon-efficient live index developed by BSE in collaboration with IIM Ahmedabad in 2012. It is the country's first objective green equity index to utilize index constituent weight capping.

- Co-developed with g-Trade Carbon Ex Ratings Services Private Limited, the index aims to evaluate and quantify the energy efficiency of firms based on energy and financial data.
- It employs a sector-specific algorithm to measure a firm's performance relative to others in the same sector.
- The index places weight on two major criteria that indicate the long-term sustainability of businesses: energy efficiency, which is assessed by factors such as reduced energy consumption, decreased wastage, adoption of renewable energy, and energy costs, and profitability.

Mission Life

Mission LiFE, also known as Lifestyle for Environment, is an expansive global initiative led by India, aiming to inspire individual and community efforts towards environmental preservation and conservation.

Fig 12.20: Key highlights of Mission LiFE

- The initiative was **inaugurated** by the Indian Prime Minister during the 26th UN Climate Change Conference of the Parties (**COP26**) in **Glasgow** in November 2021.
- Mission LiFE endeavors to **mobilize at least one billion** Indians, as well as individuals worldwide, to adopt sustainable lifestyles, thereby contributing to environmental sustainability.
- Through this global movement, sustainable objectives and climate actions undertaken by nations and individuals across the globe will be highlighted.
- It democratizes the fight against climate change, allowing everyone to play a role according to their capabilities.
- The initiative champions the **P3 model**, **pro-planet people**. It operates on the fundamental tenets of living for the planet, by the planet, and of the planet.
- Mission LiFE adopts a **three-pronged** strategy:
  - Encouraging individuals to adopt simple yet impactful environmentally friendly practices in their daily lives (demand).
  - Facilitating rapid responses from industries and markets to meet evolving demands (supply).
  - Influencing government and industrial policies to endorse sustainable consumption and production practices (policy).

Green-Ag Project

Launched on July 28, 2020, by the Union government, the Green-Ag Project aims to mitigate emissions from agriculture and promote sustainable agricultural practices, with Mizoram being one of the five states selected for implementation, alongside Rajasthan, Madhya Pradesh, Odisha, and Uttarakhand.

- **Funded** by the Global Environment Facility(**GEF**), the project is **executed** nationally by the **Department of Agriculture**, Cooperation, and Farmers' Welfare (DAC&FW), in collaboration with the Food and Agriculture Organization (**FAO**) and the Union Ministry of Environment, Forest and Climate Change (**MoEF&CC**).

- It **aims** to integrate biodiversity, climate change, and sustainable land management objectives and practices into Indian agriculture.
- The **pilot** project, scheduled to conclude on March 31, 2026, spans 35 villages, including two protected areas—the **Dampa Tiger Reserve** and the **Thorangtlang Wildlife Sanctuary**.
- **Targets**: Its targets include achieving multiple global environmental benefits across 1.8 million hectares of land, bringing 104,070 hectares of farms under sustainable land and water management, and sequestering or reducing 49 million metric tons of Carbon dioxide equivalent (CO_2eq) through sustainable land use and agricultural practices.

Long-Term Low Carbon Development Strategy (LT-LEDS)

During the 27th Conference of Parties **(COP27)** held in Sharm-el-Sheikh, Egypt from 6-18 November, 2022, India presented its Long-Term Low Emission Development Strategy to the United Nations Framework Convention on Climate Change (UNFCCC). The salient features are:

- **Focus on Rational Resource Utilization:** The strategy emphasizes the rational utilization of national resources, prioritizing energy security while transitioning from fossil fuels in a just, smooth, sustainable, and inclusive manner.
  - **National Hydrogen Mission**: India aims to become a green hydrogen hub by rapidly expanding green hydrogen production, increasing electrolyzer manufacturing capacity, and tripling nuclear capacity by 2032, aligning with overall power sector development goals.
- **Transition in Transport Sector:** Initiatives encompass expanded utilization of biofuels like ethanol blending in petrol, advocacy for greater adoption of electric vehicles, and the promotion of green hydrogen fuel usage to propel low-carbon development in the transportation sector.
- **Sustainable Urban Development**: Urbanization will persist, with an emphasis on climate-resilient and sustainable development propelled by smart city endeavors, comprehensive urban planning, energy and resource conservation measures, adherence to green building standards, and inventive waste management solutions.
- **Low Carbon Industrial Growth**: The industrial sector is poised to sustain strong growth while shifting towards low-carbon development strategies, including participation in initiatives such as the Perform, Achieve, and Trade (PAT) scheme, the National Hydrogen Mission, electrification, material efficiency improvements, expansion of circular economy practices, and the exploration of solutions for hard-to-decarbonize sectors.
- **Forest and Tree Cover Enhancement:** India has a strong record of increasing forest and tree cover, acting as a net sink for CO_2 emissions. **It is on track to meet its NDC commitment** of additional carbon sequestration by 2030.
- **Climate Finance Needs:** Transitioning to a low-carbon pathway will require significant investment in new technologies, infrastructure, and other costs. Climate finance provision, especially from developed countries, needs to be substantially increased to support India's efforts.

Key Considerations

- India's long-term low-carbon development strategy is grounded on four fundamental principles.
- **India's Contribution to Global Warming:** India has a small historical contribution to global greenhouse gas emissions despite its large population.
- **Energy Needs for Development:** India has significant energy requirements for development.
- **Commitment to Low-Carbon Strategies**: India is committed to pursuing low-carbon strategies tailored to its national circumstances.
- **Climate Resilience:** India needs to enhance climate resilience as part of its development strategy.

The strategy is based on principles of climate justice, sustainable lifestyles, equity, and common but differentiated responsibilities and respective capabilities (**CBDR-RC**), ensuring India's right to a fair share of the global carbon budget while promoting rapid growth and economic transformation in harmony with environmental protection. Additionally, it aligns with the **LiFE mission**, advocating for a global shift towards **mindful utilization rather than destructive consumption**.

GRIHA

GRIHA, or Green Rating for Integrated Habitat Assessment, was conceived by **TERI** (The Energy & Resources Institute) and developed by the **Ministry of New & Renewable Energy**.

- It serves as a rating tool to assess the ecological impact of buildings against nationally accepted benchmarks. The objective is to evaluate the environmental sustainability of buildings.

Benefits of GRIHA-certified buildings: include reduced energy consumption while maintaining comfort levels, minimized destruction of natural habitats and biodiversity, and decreased soil erosion.

- Additionally, they contribute to lower air and water pollution, leading to direct health benefits, and reduce water consumption.
- These buildings also generate limited waste through recycling and reuse, lessen pollution loads, enhance user productivity, and improve image and marketability.

FAME India

Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME India) Scheme, a part of the National Electric Mobility Mission Plan, seeks to encourage the uptake of electric and hybrid vehicles through upfront incentives.

- The program covers a range of hybrid and electric technologies, including Mild Hybrid, Strong Hybrid, Plug-in Hybrid, and Battery Electric Vehicles.
- **Phase I** of FAME India, which ran from 2015 to March 31, 2019, had an allocation of Rs 895 crore. It focused on technology development, demand creation, pilot projects, and charging infrastructure.
  - During this phase, approximately 2.78 lakh xEVs received support through demand incentives, and 465 buses were sanctioned.
- **Phase II**, implemented by the Ministry of Heavy Industries over five years starting from April 1, 2019, has a budget of Rs. 10,000 crore.
  - This phase prioritizes the electrification of public and shared transportation, offering demand incentives for eBuses, e-3 Wheelers, e-4 Wheeler Passenger Cars, and e-2 Wheelers.
  - Additionally, the scheme supports the development of charging infrastructure.

Decarbonisation of Indian Economy

Decarbonization refers to the process of reducing or eliminating carbon dioxide emissions, particularly those generated by human activities such as burning fossil fuels. This process aims to mitigate climate change by transitioning to cleaner and more sustainable energy sources, increasing energy efficiency, and implementing carbon capture and storage technologies.

Challenges in decarbonisation: Decarbonizing industries poses significant challenges, both **technically and economically.**

- One major obstacle is the difficulty in reducing carbon dioxide (CO_2) emissions, especially when they stem from **essential feedstocks** that cannot easily be replaced without affecting dependent processes.
- Furthermore, transitioning from fossil fuels to green sources of electricity or energy to generate high-temperature, high-pressure steam requires substantial **modifications to furnaces** and **burners**, adding to the complexity and cost of decarbonization efforts.
- Economically, the high investment levels required for technology transitions are often prohibitive.

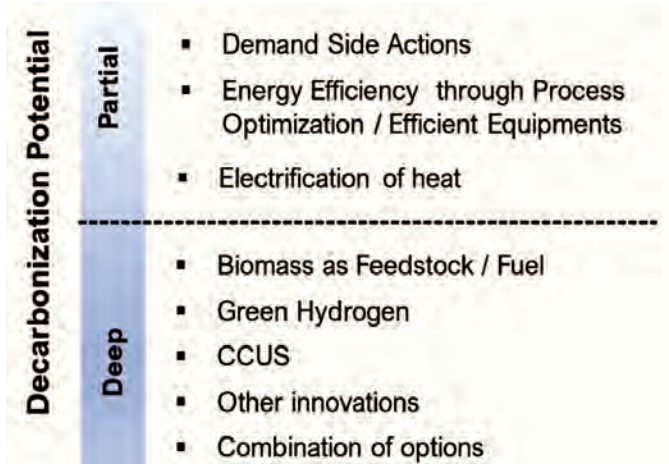


Fig 12.22: Categorisation of Decarbonisation potential

- **Projects** in these sectors are typically large-scale and have **long lifespans**, making process changes and retrofits complex, **costly**, and requiring meticulous planning.
- Moreover, such changes could impact the **marketability of final products**, as increased capital and operating **expenses** would likely raise prices.
- Given that products like cement, fertilizers, petrochemicals, and steel are commodities traded globally, producers are often hesitant to adopt low-carbon processes and technologies due to the **price sensitivity** of these markets.

TERI's roadmap outlines strategies for attaining India's decarbonization objectives:

- Increasing the share of **decentralized solar power** can be achieved by introducing a **feed-in-tariff** that attracts private investment and is approved by the State Electricity Regulatory Commission.
- State leadership should drive the development of pumped storage plants and implement feed-in-tariffs for solar generation.
- Implementing **feed-in-tariffs** in the kilowatt range has the potential to **boost farmer incomes**, create employment opportunities, and enhance the quality of power supply in rural areas.
- Exploring new energy storage solutions is essential to bring stability and flexibility to the grid, complementing existing policies.
- Flexibility must be integrated into the power system to accommodate the generation from wind and solar sources effectively.
- India should prioritize becoming a cost-effective and competitive manufacturing hub for renewable energy, supported by initiatives like the Production Linked Incentive (PLI) scheme.

- Expanding the PLI scheme to cover various renewable energy equipment production, including solar panels, mirrors, sensors for solar thermal, batteries for grid use, and hydrogen, is crucial.
- DISCOMs should provide Commercial and Industrial consumers with the option to purchase carbon-free electricity in real-time, with separate tariffs.

Long Term Ecological Observatories

The LTEO Programme, launched by the **Ministry of Environment, Forests, and Climate Change (MOEFCC)** facilitated by a network of scientific institutions, seeks to comprehend the **biophysical** and human-induced factors driving ecosystem changes in specific biomes and their impact on **socio-ecological** responses. It involves experimental **assessments of natural ecosystem** structure and function, as well as monitoring various indicators such as freshwater fish, birds, mammals, herbivores, carnivores, animal movements, soil processes in forests and grasslands, and biophysical climatic variables to identify patterns and drivers of change.

National Green Hydrogen Mission

The Green Hydrogen Mission stands as a pivotal Indian initiative against climate change, aiming to propel the commercial production of green hydrogen and position India as a net exporter of this **eco-friendly fuel.**

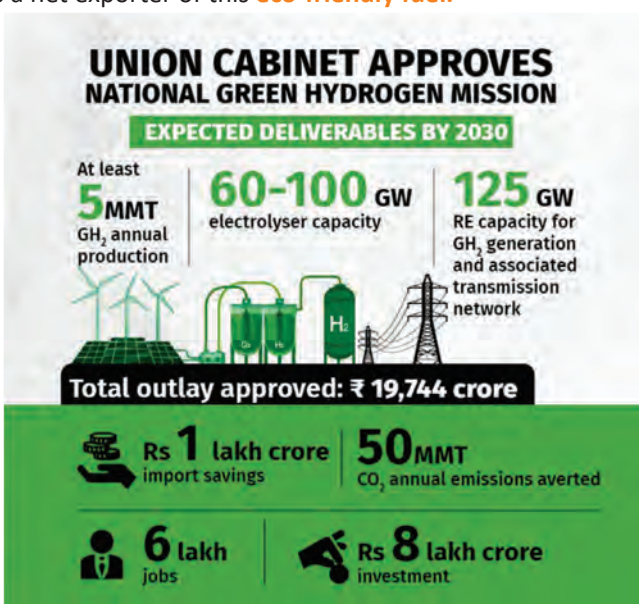


Fig 12.23: National Green Hydrogen Mission

- **Mission Outcomes**

1. **SIGHT Programme:** Under the Strategic Interventions for Green Hydrogen Transition Programme (SIGHT), two distinct financial incentive mechanisms – targeting domestic manufacturing of electrolysers and production of Green Hydrogen – will be provided under the Mission.
2. **Pilot projects:** The Mission will also support pilot projects in emerging end-use sectors and production pathways. Regions capable of supporting large scale production and/or utilization of Hydrogen will be identified and developed as Green Hydrogen Hubs.
3. **R&D Projects:** Public-Private Partnership framework for R&D (Strategic Hydrogen Innovation Partnership – SHIP) will be facilitated under the Mission. R&D projects will be goal-oriented, time bound, and suitably scaled up to develop globally competitive technologies.
4. **Skill Development:** A coordinated skill development programme will also be undertaken under the Mission.

- With ambitious objectives to develop a green hydrogen production capacity of at least 5 MMT per annum by 2030 and add 125 GW of renewable energy capacity, the mission is projected to attract investments exceeding Rs 8 lakh crore, generate six lakh jobs, and substantially reduce fossil fuel imports and greenhouse gas emissions.
- Spearheaded by the **Ministry of New and Renewable Energy**, this initiative is poised to drive the decarbonization of key sectors, diminish reliance on imported fossil fuels, foster indigenous manufacturing, create employment avenues, and foster the advancement of innovative technologies like efficient fuel cells.

Decentralization of Climate Action in India

The proposal to establish India's Intra-national COP (IndiaCOP), akin to the GST council, aims to foster national consensus on India's climate objectives and strategies for their attainment.

- **IndiaCOP** can foster cooperative and competitive federalism by encouraging each state/UT to commit to more ambitious actions toward achieving net-zero emissions.
- Notably, IndiaCOP can facilitate the development of tailored approaches for embracing climate goals in alignment with the socio-economic and cultural nuances of each region.
- By bolstering local resilience, communities can better anticipate and respond to climate risks and crises, thereby reshaping long-term development trajectories.
- Local governments, being the closest to communities, are pivotal in disaster response and can coordinate effective actions while ensuring community engagement.
- For instance, **Palli Gram Panchayat in J&K** has formulated a climate-resilient plan to raise awareness and implement climate mitigation efforts at the grassroots level.

Assessment of India's Climate Change Mitigation Efforts

Being the world's third-largest emitter of greenhouse gases, India often faces criticism from the international community. However, India justifies its position by emphasizing its comparatively low per capita emissions and historical emissions in contrast to developed nations.

Let us analyze Indian efforts in climate change mitigation:

- **Nationally Determined Contributions (NDCs) Achievement**: India's 2015 NDCs aimed at increasing non-fossil power capacity to 40% and reducing emissions intensity by 33-35% by 2030. These targets were surpassed, with emissions already reduced by 24% by 2016. Revised NDCs were introduced in 2022.
- **Transition from Coal Power**: The utilization rate of coal power plants is declining, with some major mines operating at only 1% capacity, according to Global Energy Monitor (GEM) analysis.
- **Promotion of Electric Vehicles (EVs):** India introduced schemes like FAME and tools like the e-Amrit portal to boost EV sales, resulting in a 185% year-on-year increase in EV sales in October 2022.
- **Forest Conservation and Reforestation**: While India aims to restore 26 million hectares of deforested land and sequester 2.5-3 billion tons of CO_2 by 2030, more funding is needed to catalyze forest conservation and reforestation efforts.
- **Sovereign Green Bonds:** The 2022-23 Union Budget announced sovereign green bonds under government market borrowings to fund climate-friendly infrastructure. Continued issuance and exploration of blue bonds are essential for enhancing climate action.

Despite India's significant contribution to global climate action, challenges remain, especially with a large population living in poverty. More international climate finance is needed, with India advocating for the operationalization of UNFCCC finance mechanisms at COP27.

Best Practices Followed by India

India has executed many novel multi-sectoral interventions in its fight against climate change like:

- **Renewable Energy Promotion:** Setting ambitious targets like **175 GW of renewable** energy capacity by 2022, with schemes like the **National Solar Mission** and **Wind Energy** Program.
- **Energy Efficiency Initiatives:** Launching programs such as **Perform, Achieve and Trade (PAT)** to reduce energy consumption in industries and introducing energy efficiency labeling for appliances and buildings.
- **Electric Vehicle Promotion:** Encouraging electric vehicle adoption through the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (**FAME**) scheme.
- **Afforestation and Reforestation:** Undertaking efforts to increase forest cover and carbon sequestration through initiatives like the **Green India Mission** and the **Bonn Challenge**.
- **Climate Finance Mobilization:** Actively engaging in accessing and utilizing climate finance through initiatives like the **National Adaptation Fund** and **Green Climate Fund (GCF)** projects.

These efforts underscore India's commitment to combating climate change and transitioning towards a sustainable future.

IGNITE YOUR MIND

Offsetting the Footprint: Imagine a magical carbon eraser that allows you to compensate for your emissions by supporting sustainable projects. Is this a guilt-free solution, or are there hidden consequences and complexities to consider?

Challenges Faced by India in Climate Change Mitigation and Management

India faces several challenges in both climate mitigation and adaptation efforts like:

- **Limited Resources:** India, as a developing country, faces resource constraints in implementing large-scale climate mitigation and adaptation projects. Limited financial resources hinder the deployment of clean energy technologies and the implementation of robust adaptation measures.
- **Population Pressure:** India's large and growing population adds pressure on natural resources and exacerbates climate-related challenges. Rapid urbanization and industrialization further strain resources and contribute to increased emissions.
- **Vulnerability to Climate Impacts:** India is highly vulnerable to the impacts of climate change, including extreme weather events like cyclones, floods, and droughts. These events disrupt livelihoods, damage infrastructure, and threaten food and water security, particularly in rural and coastal areas.
- **Technological Barriers:** Despite advancements, access to and adoption of advanced clean energy technologies remain limited in many parts of India. The high initial costs of renewable energy infrastructure and lack of technological expertise pose significant barriers to scaling up renewable energy deployment.
- **Policy Implementation:** While India has developed comprehensive climate policies and action plans, effective implementation at the ground level remains a challenge. Inadequate enforcement mechanisms, bureaucratic hurdles, and lack of coordination among various stakeholders hinder the successful execution of climate initiatives.
- **International Cooperation:** India faces pressure to mitigate emissions while balancing its developmental priorities. Negotiating international agreements that address climate change while ensuring economic growth and poverty alleviation is a complex challenge.

Way Forward: India should broaden its focus on solar energy by promoting alternatives such as floating solar and offshore wind projects, which offer high energy yield without requiring large land areas.

- However, expanding the non-fossil fuel base will depend heavily on developing a more extensive energy storage system, a challenge given the global lithium market situation.
- Climate investment planning involves understanding planning capacity, identifying investment needs, and mobilizing resources.
- Learning from **Jordan's** example, India can establish sector working groups to prioritize actions based on criteria like impact, gender and vulnerability issues, sustainable development potential, and readiness.
- Supporting project development in the early stages and assisting developers in securing funding opportunities can help bridge the funding gap.
- Additionally, India should develop sectoral investment and engage the private sector to support its Nationally Determined Contributions (NDCs).
- Strengthening national sector capacities to access and coordinate climate finance, increasing industry and financial decision-makers' involvement in the NDC process, and fostering political leadership with the private sector can help elevate ambition and showcase mutual benefits.

CLIMATE FINANCE

Climate finance refers to funding, whether regional, national, or transnational, sourced from diverse channels such as public, private, and alternative sources. Its objective is to support efforts for both mitigating and adapting to climate change. Both the **Kyoto Protocol and the Paris Agreement** emphasize the importance of financial support from wealthier parties to less affluent and vulnerable ones, acknowledging the differing contributions to climate change and capacities to address it.

Mitigation requires substantial investments to reduce emissions, while adaptation also necessitates significant financial resources to cope with the adverse impacts of climate change. **Developed countries** are obligated to provide financial support to developing countries under the principle of "**common but differentiated responsibility and respective capabilities**" outlined in the Convention.

The **Paris Agreement** reinforces these obligations for developed countries while encouraging voluntary contributions from others. Mobilizing climate finance from a variety of sources, instruments, and channels is crucial, with public funds playing a significant role. The focus should be on supporting country-driven strategies and considering the needs and priorities of developing countries.

Understanding the financial needs of developing countries and mobilizing resources accordingly is essential. Achieving a balance between adaptation and mitigation efforts is paramount. The Paris Agreement aims to **align finance flows with low greenhouse gas emissions and climate-resilient development**. Transparency and predictability in financial support are emphasized, with progress assessed through the global stocktake process under the Agreement.

Need for Climate Finance

- **Global Scale of Investment Required:** According to the 2022 World Economic Forum, increasing funding is essential to assist people in adapting to climate change and avoid its worst consequences.
  - A staggering **$5.7 trillion** annually is needed globally for green infrastructure, adaptation, and mitigation efforts. This necessitates unprecedented creativity and commitment from both governments and the private sector.
- **Mitigation:** Substantial investments are essential for making significant reductions in emissions and combating climate change.
- **Adaptation:** Substantial financial resources are required to adapt to the adverse effects of climate change and minimize its impacts.
- **Support for Developing Countries:** It's crucial to assist developing countries in enhancing their resilience to worsening climate impacts and stimulating private sector climate investment.
- **Transition to a Low-Carbon Economy:** Climate finance is essential to shift the global economy towards a low-carbon trajectory, especially as direct government funding is limited in many countries.

India's Investment Needs: Under the Paris Accord, India has pledged to reduce its carbon emission intensity by 33-35%. Achieving these targets and expanding its renewable capacity necessitates climate finance.

- **Growing Green Bond Market:** India's green bond market is expanding, with the first green bonds issued in 2015, highlighting the need for further exploration of climate financing options.
- **Challenges in India's Financial Sector:** In India, banks and non-banking financial companies face constraints in long-term debt financing due to asset-liability mismatches.
- **Multiple Challenges Faced by India:** India grapples with traditional issues such as poverty, pollution, and education gaps alongside climate change challenges, underscoring the heightened need for climate finance.

Some of the key mechanisms and agencies involved in climate finance are as follows:

1. Global Environment Facility (GEF)

The Global Environment Facility (GEF) was established in October 1991 as a pilot program with the World Bank to aid in the protection of the global environment and the promotion of environmental sustainability. It was reformed and established as a permanent, distinct organization during the 1992 Rio Earth Summit with the purpose of assisting in the resolution of the world's most significant environmental concerns.

The GEF is jointly managed by the United Nations Development Programme (UNDP), the World Bank, and the United Nations Environment Programme (UNEP).

- The **World Bank** acts as the **trustee** for the GEF, overseeing the administration of the fund.
- GEF funding is accessible to developing nations and countries undergoing economic transition, aiming to assist them in achieving the objectives outlined in various international environmental conventions and agreements.
- As a "**financial mechanism**," GEF supports five key Conventions:
  - **United Nations Convention on Biological Diversity (UNCBD)**
  - United Nations Framework Convention on Climate Change (UNFCCC)
  - Stockholm Convention on Persistent Organic Pollutants (POPs)
  - UN Convention to Combat Desertification (UNCCD)
  - Minamata Convention on Mercury.

GEF Council

- The GEF Council, the principal governing body of the GEF, comprises 32 members selected by constituencies representing GEF member nations. This includes 14 members from developed countries, 16 from developing countries, and two from economies in transition.
- India has established a permanent Constituency in the GEF Executive Council, along with Bangladesh, Sri Lanka, Bhutan, Nepal, and Maldives.
- Council members rotate at varying intervals determined by each constituency, and the Council convenes twice annually.
- It is responsible for developing, adopting, and evaluating operational policies and programs for GEF-financed activities.
- Additionally, the Council reviews and approves the work program, making decisions through consensus.

2. Green Climate Fund (GCF)

Established in 2010 as part of the UNFCCC's financial framework, the Green Climate Fund channels funds from wealthier nations to developing countries to support climate change mitigation and adaptation efforts.

- Headquartered in **Incheon, South Korea,** the GCF operates with the World Bank serving as its interim trustee.
- It is designed to play a central role in the collective effort to mobilize $100 billion in climate finance by 2020.
- The GCF has adopted a balanced approach, allocating funds **equally between mitigation and adaptation** efforts.
- Additionally, it aims to ensure that **at least 50 percent of the adaptation** allocation goes to **particularly vulnerable** countries, including Least Developed Countries (LDCs), Small Island Developing States (SIDS), and African States.

3. The Special Climate Change Fund (SCCF)

Established during the 2001 Conference of the Parties (COP) to the UNFCCC, the Special Climate Change Fund (SCCF) is **administered** by the Global Environment Facility (**GEF**), serving as an operational arm.

- With a focus on financing projects related to adaptation, technology transfer, and capacity building, the SCCF targets vulnerable developing countries, offering support across various sectors like energy, transportation, industry, agriculture, forestry, waste management, and economic diversification.
- The SCCF plays a pivotal role in enabling the integration of resilience and adaptation into broader initiatives backed by the GEF trust fund.
- Moreover, it enhances disaster prevention capabilities and assists in monitoring diseases and vectors affected by climate change. It aids countries in adopting climate change technologies, conducting research, and implementing deployment and demonstration projects.

4. Biocarbon Fund Initiative

The BioCarbon Fund Initiative for Sustainable Forest Landscapes (ISFL) is a multilateral fund, backed by donor governments and overseen by the **World Bank.**

- Its primary aim is to diminish greenhouse gas emissions from the land sector, encompassing initiatives to curtail deforestation and forest degradation in developing countries (REDD+), promote sustainable agriculture, and advance smarter land-use planning, policies, and practices.
- Currently, the ISFL supports initiatives in Colombia, Ethiopia, Indonesia, Mexico, and Zambia. These extensive programs are at the forefront of efforts to facilitate countries and the private sector in implementing changes in farming practices on the ground, while also informing international policymaking.

5. Clean Technology Fund

The Clean Technology Fund (CTF) facilitates the transition to clean energy in developing nations by providing resources to expand low-carbon technologies with significant potential for long-term greenhouse gas emissions reduction.

- **Managed by the World Bank**, the CTF has a funding allocation of $5.2 billion to support its initiatives.
- The fund supports various clean technologies across renewable energy, energy efficiency (in buildings, agriculture, and industry), and clean transportation sectors.
- Utilizing a blend of financial instruments such as grants, contingent grants, concessional loans, equity, and guarantees, the CTF aims to incentivize investments in low-carbon technologies for both public and private investors in low- and middle-income countries.

- Under the leadership of recipient countries, investment plans are devised to identify major sources of greenhouse gas emissions and mitigation opportunities, tailored to national priorities.
- The fund then mobilizes co-financing and enhances access to capital for clean energy projects by encouraging financial institutions to establish lending programs for private companies. Additionally, countries can pursue projects prioritizing private-sector investments in specific thematic technology areas.

6. Forest Carbon Partnership Facility (FCPF)

The FCPF is a global coalition comprising governments, businesses, civil society, and indigenous peoples' organizations, with a focus on reducing emissions from deforestation and forest degradation, conserving forest carbon stocks, sustainably managing forests, and enhancing forest carbon stocks in developing countries, commonly known as REDD+ activities.

- Established in 2008, the FCPF collaborates with 47 developing nations across Africa, Asia, and Latin America and the Caribbean, along with 17 donors who have collectively contributed and pledged $1.3 billion.

The FCPF supports REDD+ initiatives through two distinct yet complementary funds.

- The **FCPF Readiness Fund** aids countries in establishing the foundational elements for implementing REDD+.
  - This includes formulating national REDD+ strategies, establishing reference emission levels, designing measurement, reporting, and verification systems, and establishing national REDD+ management frameworks, including appropriate environmental and social safeguards. Current funding: $400 million.
- The **FCPF Carbon Fund** implements results-based payments to countries that have progressed through REDD+ readiness and implementation stages, achieving measurable emission reductions in their forest and broader land-use sectors. Current funding: $900 million.

7. REDD and REDD+

REDD refers to the United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation, headquartered in **Geneva, Switzerland**, comprises 64 partner countries.

- It operates as a multilateral collaborative effort involving the Food and Agriculture Organization of the United Nations (**FAO**), the United Nations Development Programme (**UNDP**), and the United Nations Environment Programme (**UNEP**).
- Established in 2008 following UNFCCC decisions on the **Bali Action Plan** and REDD at **COP-13**, the program assists developing countries in building technical capacities for REDD+ implementation and meeting UNFCCC requirements for results-based payments.

The "Plus" in **REDD+** encompasses various activities like conservation, sustainable forest management, and enhancement of forest carbon stocks.

- REDD+ operates in three phases: Readiness, Implementation, and Result-based actions. The Readiness phase involves developing national strategies, mitigation actions, and capacity building.
- Implementation focuses on enacting REDD+ actions and strategies, which may include further capacity building and technology transfer. Result-based payments constitute the final phase, providing financial incentives to countries that demonstrate reduced deforestation.
- The **Green Climate Fund (GCF)**, established at COP-17 as the financial mechanism for the UNFCCC, currently **funds REDD+** programs. Brazil was the first country to receive $96.5 million in results-based payments.

8. Adaptation Fund

The Adaptation Fund (AF) was established in 2001 with the aim of funding practical adaptation projects and programs in developing countries that are particularly vulnerable to the adverse impacts of climate change.

- **Funding** for the Adaptation Fund comes from a portion of proceeds generated by **clean development mechanism** (CDM) project activities, along with other funding sources.
- Specifically, 2% of certified emission reductions (CERs) issued for a CDM project activity contribute to the fund.
- Supervised and managed by the Adaptation Fund Board (AFB), the Global Environment Facility (GEF) provides secretariat services to the AFB upon invitation from Parties, while the World Bank serves as the interim trustee of the Adaptation Fund.
- The Adaptation Fund Board's secretariat, based in Washington DC, comprises an international team that offers research, advisory, administrative, and various other services to the Board.

9. Loss and Damage Fund

The Loss and Damage (L&D) fund functions as a financial mechanism intended to address the irreversible impacts of climate change that cannot be managed through adaptation measures.

- It acknowledges and aims to compensate for the real losses suffered by communities, nations, and ecosystems as a result of climate change effects, considering **not only monetary value but also human rights, well-being, and environmental sustainability.**
- Established formally during the 19th Conference of the Parties **(COP 19)** to the United Nations Framework Convention on Climate Change (UNFCCC) in Warsaw, Poland, in 2013, the L&D fund was created to offer financial and technical support to economically developing countries facing Loss and Damage due to climate change.

- The 2021 **COP26** climate summit in **Glasgow** sought to continue deliberations on the operationalization of the fund in the forthcoming years.
- The announcement of the loss and damage fund initially occurred during **COP27** in Sharm el-Sheikh, Egypt.
- Subsequently, during the opening day of the **COP28** climate conference in Dubai, the loss and damage fund was **officially launched.**
- Initial funding for the fund is estimated at $475 million, with contributions from various entities including the host UAE ($100 million), the European Union ($275 million), the US ($17.5 million), and Japan ($10 million).

10. Debt-for-Climate Swaps

Debt-for-climate swaps entail a financial arrangement wherein a heavily indebted nation receives debt relief in exchange for investing in climate change mitigation or adaptation projects.

- Over the past decade, this approach has gained popularity among low- and middle-income countries. Multilateral development banks and organizations like the United Nations Development Programme (UNDP) advocate for this mechanism as a means of debt relief.
- Both **official bilateral and commercial debts** can be involved, with bilateral swaps involving redirecting debt service payments towards mutually agreed climate projects.
- The **first** such swap occurred in 2006 between **Germany and Indonesia**, with Indonesia committing to reduce greenhouse gas emissions through forest conservation in exchange for debt relief.
- Small island developing states **(SIDS)** are increasingly considering debt-for-climate swaps to address their dual challenges of climate risk adaptation and financial stability.

11. Capacity-Building Initiative for Transparency (Cbit) Fund

The Capacity-building Initiative for Transparency (CBIT) Fund is a direct outcome of the Paris Agreement established by the UNFCCC in 2015. Its primary objective is to address transparency issues by assisting developing countries in monitoring and reporting their progress on climate actions. The fund, which will be established by the Global Environment Facility (GEF), receives financial support from developed nations such as the US, UK, and Canada, etc.

12. Least Developed Countries Fund

The Least Developed Countries Fund (LDCF) was established at the 7th Conference of the Parties in 2001 (COP7) operational since 2002, was created to meet the adaptation needs of least developed countries (LDCs). The LDCF has supported the preparation and implementation of **National Adaptation Programs of Action (NAPAs)** and is administered by the GEF with the World Bank serving as Trustee.

Climate Finance Challenges

Climate finance faces numerous challenges ranging from political will to geopolitics, while also including the global economic architecture. Some of the challenges are:

- **Insufficient Funding:** Despite commitments, there remains a significant gap between the funds required for climate mitigation and adaptation and the resources available.
  - For example, the **100 billion dollar** commitment by the developed countries continues to be elusive.
- **Limited Access:** Developing countries often face barriers in accessing climate finance due to stringent eligibility criteria and complex application processes, hindering their ability to implement crucial projects.
  - At **COP28**, developing countries called out for reform in the way financial institutions deal with developing countries in their finance needs.
- **Investment Barriers:** Perceptions of high risk, a lack of bankable projects, and regulatory uncertainties deter private sector investment in climate-friendly initiatives, impeding efforts to mobilize additional financial resources.
  - For instance, **green bonds** are still not perceived to be attractive enough for investment.
- **Allocation Issues:** Ensuring equitable distribution of funds is essential to ensure that vulnerable communities receive adequate support, yet challenges persist in achieving this goal.
- **Transparency and Accountability:** Despite efforts, ensuring transparency in funding allocation and tracking the impact of climate finance remains challenging, raising concerns about accountability and effectiveness.
- **Green Accounting:** It continues to be an evolving topic and there is no universal acceptance on what is the cost of an "offset," "credits," etc.

Way Forward

- **Scaling Up Funding:** Mobilizing additional financial resources from governments, international organisations and private sector investors to bridge the finance gap.
- **Simplifying Access:** Streamlining procedures and providing technical assistance to enhance developing countries' access to climate finance.
- **Risk Mitigation:** Implementing risk-sharing mechanisms, insurance instruments, and credit enhancements to attract private sector investment in climate projects.
- **Capacity Building:** Strengthening the capacity of developing countries to develop bankable climate projects and effectively manage climate finance.
- **Enhanced Monitoring:** Implementing robust monitoring and evaluation mechanisms to ensure transparency, accountability, and effectiveness of climate finance initiatives.

- **Exploration of Innovative Financing Mechanisms:** Investigating inventive financial tools like green bonds, carbon pricing, and climate funds to mobilize extra resources and encourage sustainable investments.

It is imperative for developed countries to collaborate with and support developing nations in transitioning to clean energy and securing financing for climate-resilient infrastructure. This ensures fulfillment of the $100-billion goal.

Finance will remain a **central focus** of the climate change discourse in the foreseeable future, permeating discussions at prominent forums where heads of states converge, such as the **G7 and G20**. There's a growing demand for major economies to assume their fair share of responsibility, particularly concerning loss and damage financing, debt restructuring and relief, and adaptation funding. With increasingly frequent catastrophic climate events, the urgency for significant financial commitments to assist vulnerable nations in combating climate change has reached a pivotal juncture.

CLIMATE FINANCE IN INDIA

1. The National Adaptation Fund for Climate Change (NAFCC)

Established in the fiscal year 2015-16, the National Adaptation Fund for Climate Change (NAFCC) operates as a Central Sector Scheme.

- Its primary objective is to **finance tangible adaptation initiatives** that alleviate the adverse impacts of climate change.
- Projects funded under NAFCC are executed on a project basis, focusing on sectors like agriculture, animal husbandry, water, forestry and tourism.
- The **National Implementing Entity** (NIE) for NAFCC is the National Bank for Agriculture and Rural Development (**NABARD**).
- **Implementation process:** States and Union Territories collaborate with NABARD to develop project proposals.
  - Project proposals must gain approval from the State Steering Committee on Climate Change to qualify for NAFCC funding.
  - States have the discretion to engage any organization for assistance in project preparation, according to their needs.

2. National Clean Energy Fund

Established during the fiscal year 2010-11, the National Clean Energy Fund (NCEF) serves as a dedicated financial resource for promoting clean energy initiatives.

- **Funding Mechanism:**The fund is primarily financed through a cess imposed on coal production and imports, adhering to the "**polluter pays**" principle.
- **Utilization of Funds:** NCEF finances research and innovative projects in clean energy technologies, extending support of up to 40% of the total project cost to both public and private sector entities.
- Projects focused on innovative methods for adopting clean energy technology and conducting research and development are eligible for funding from the NCEF.
- Assistance is provided in the form of loans or viability gap funding, depending on the evaluation by an Inter-Ministerial Group tasked with assessing project merits.
- **Administration of NCEF:** The NCEF is structured as a non-lapsable fund under **Public Accounts**, with its secretariat housed within the Department of Expenditure, Ministry of Finance.
  - An Inter-Ministerial Group, led by the Finance Secretary in the Ministry of Finance, evaluates and recommends projects suitable for funding through the NCEF.

3. Sovereign Green Bonds

In the Union Budget 2022-23, Finance Minister Nirmala Sitharaman announced the issuance of sovereign green bonds to raise funds for 'green projects' aimed at reducing carbon emissions.

- **Utilization of Proceeds:** The proceeds from these bonds, raised through RBI auctions, will be allocated to fund public sector projects focusing on renewable energy, clean transportation, green buildings, and other environmentally sustainable initiatives.
- **Framework Implementation:** Under the established framework, the Finance Ministry will annually report to the RBI regarding the allocation of funds for specific green projects, ensuring transparency and accountability in resource utilization.
- **Green Finance Working Committee (GFWC):** To oversee the implementation of the framework, the **Ministry of Finance** has formed a GFWC, comprising members from relevant ministries, the committee is **chaired by the Chief Economic Advisor.**
  - The GFWC will convene biannually to assist the Ministry of Finance in project selection, evaluation, and other tasks related to the framework, facilitating effective management and execution of green projects.

4. Blue bonds

Blue bonds represent a distinct category of sustainable bonds tailored to fund initiatives aimed at preserving and rejuvenating the ocean and its assets.

- **Green Vs Blue bonds:** While akin to green bonds and social bonds in principle, blue bonds are uniquely dedicated to promoting ocean conservation and sustainable growth.

- Issued by various entities including governments and development banks, blue bonds are accessible to a range of investors, including individuals, institutions, and financial organizations.
- **SEBI's** ongoing **development of guidelines** for blue bonds in India signals the potential for these instruments to support numerous projects benefiting the country's marine ecosystem and economy once implemented.

Green GDP and Green National Account

These are concepts aimed at assessing a country's economic performance while factoring in environmental implications.

- **Green GDP,** also referred to as **environmentally adjusted** domestic product, deducts the costs of natural resource depletion and environmental degradation from the conventional GDP, offering insights into the sustainability of economic growth and its impact on societal well-being.
- **Green National Account** integrates environmental considerations into national accounting frameworks, striving to quantify the environmental costs and benefits linked to economic activities. Through green accounting methods, it seeks to evaluate the value of natural resources, the expenses associated with pollution and environmental damage, and the advantages of ecosystem services.

5. Compensatory Afforestation Fund

The Compensatory Afforestation Fund (CAF) is a dedicated fund established to finance afforestation and reforestation initiatives as compensation for the diversion of forest land for non-forest purposes.

- It aims to mitigate the environmental impact of such diversions by ensuring the restoration and enhancement of forest cover elsewhere.
- The fund is primarily sourced from payments made by entities undertaking activities that result in forest land diversion, and it is utilized for various afforestation and reforestation projects across the country.
- The Compensatory Afforestation Fund Management and Planning Authority is a statutory body established to oversee the management and utilization of funds collected under the Compensatory Afforestation Fund Act, 2016 (CAF Act).
- 90% of the Compensatory Afforestation Fund (CAF) allocation will be directed to the states, with the remaining 10% is retained by the central government.
- These funds are designated for various purposes, including enhancing catchment areas, supporting natural regeneration efforts, managing forests, protecting and conserving wildlife, relocating villages from protected zones, mitigating human-wildlife conflicts, conducting training and awareness programs, and providing wood-saving devices and related initiatives.

6. Reserve Bank of India (RBI) joined the Network for Greening the Financial System (NGFS).

The Network for Greening the Financial System (NGFS) is an international coalition of **central banks** and supervisory bodies dedicated to promoting a sustainable financial framework.

- Its objective is to assess the impacts of climate change on the financial sector and redirect worldwide financial resources to support low-carbon economic development.
- Established during the **Paris One Planet Summit** in December **2017**, its administrative hub is hosted by the Banque de France.
- The Reserve Bank of India (RBI) anticipates leveraging its NGFS membership to both learn from and contribute to global endeavours in climate finance, particularly amid the growing significance of climate change concerns.

7. PACEsetter Fund Programme

The PACEsetter Fund is a collaborative initiative established jointly by the USA and India. Its mission is to accelerate the adoption of innovative off-grid clean energy solutions through initial grant funding.

- This financial support empowers businesses to pioneer and assess new products, business models, and systems.
- The main objective of the Fund is to bolster the sustainability of off-grid renewable energy enterprises that deliver small-scale (less than 1 megawatt) clean energy systems to individuals and communities without access to grid-connected power or facing limited/ intermittent access.

Climate Finance Challenges in India

In addition to the above mentioned challenges for global climate financing, India specific challenges are:

- **Climate Finance Debate and Definitions:** The concept of climate finance, including the notion of additivity, is subject to debate, with varying estimation methodologies complicating India's funding requirements. Insufficient private sector involvement exacerbates the funding gap.
- **Equity and Responsibility Challenges:** Disagreements over equity and common but differentiated responsibility complicate climate finance discussions. India's estimated climate finance needs lack clarity in terms of mobilization, provision, and utilization.
- **Financial Flow and Utilization Issues:** Discrepancies between reported climate finance flows, actual fund disbursements, and their utilization exist.
  - Independent reviews of India's National Action Plan on Climate Change highlight financial estimate ambiguities and a lack of clear prioritization criteria.

Way Forward

- **Private sector engagement:** Encouraging active participation of the private sector in climate finance initiatives through incentives, partnerships, and regulatory frameworks to mobilize additional investment and expertise.
  - According to estimates, **climate tech venture capital funding in India** from 2016 to 2021 amounted to just $1 billion, significantly lower than the approximately $15 billion in Europe, $20 billion in China, and nearly $50 billion in the United States.
- **Innovative financial tools:** Leveraging a mix of innovative financial instruments such as green bonds, climate funds, and impact investing to diversify funding sources and attract private capital for climate-related projects.
- **International collaboration:** Strengthening partnerships with international institutions and leveraging global initiatives to access additional funding, technical assistance, and knowledge sharing for climate finance in India.
  - India's finance minister, **Nirmala Sitharaman**, has utilized India's G20 presidency, to highlight the need for reforms in Multilateral Development Banks. These reforms aim to enable increased concessional finance to developing nations like India.
- **Promoting innovation and R&D:** Investing in climate-focused innovation and research and development (R&D) initiatives to develop and deploy cutting-edge technologies and solutions that address climate challenges efficiently and sustainably.
- **Additional measures** India should undertake include: formulating sector-specific investment plans and engaging the private sector to support its NDC goals, enhancing national sectoral capabilities to access and coordinate climate finance, and bolstering involvement of industry and financial leaders in the NDC process, including partnerships and project development.

India's climate finance strategy must align with its **LT-LEDS framework**, focusing on boosting renewable energy, expanding biofuel adoption, increasing electric vehicle penetration, enhancing energy efficiency, tripling nuclear capacity, and establishing green hydrogen manufacturing. A piecemeal approach risks delaying the transition and missing the opportunity to become a **green superpower.** A holistic strategy will maximize access to capital, accelerating India's climate transition efficiently.

CLIMATE JUSTICE

According to **UNDP**, "Climate justice means putting equity and human rights at the core of decision-making and action on climate change." The concept has frequently been invoked to denote the **unequal historical accountability** held by countries and communities concerning the climate crisis.

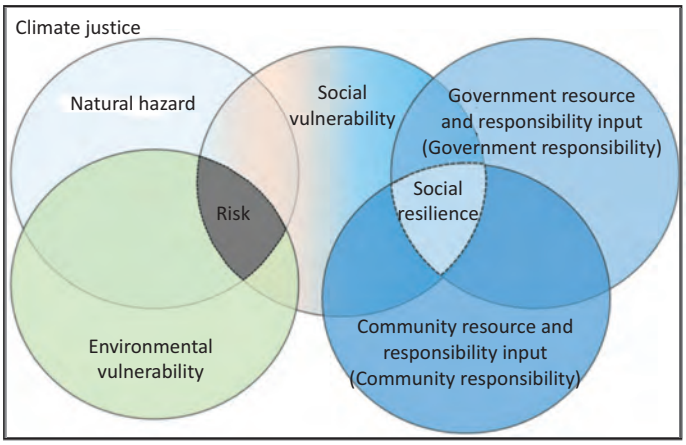


Fig 12.24: Conceptualized indicators of climate justice

Facets of Climate Justice

- **Structural Inequalities:** Climate change impacts are often experienced unevenly within the same country, reflecting structural inequalities rooted in factors such as race, ethnicity, gender, and socioeconomic status.
  - **Women,** for instance, tend to bear a disproportionate burden of climate change effects due to limited access to resources for adaptation and resilience.
  - Similarly, individuals with disabilities face heightened risks, including threats to their health, food security, access to water, energy, and sanitation, as well as their livelihoods, especially in developing nations.
  - Furthermore, **Indigenous Peoples**, who safeguard about **80%** of the world's biodiversity, are increasingly vulnerable to threats and dangers posed by climate change to their lives, ways of living, and traditional knowledge.
- **Socioeconomic Inequalities:** Climate change affects different regions and populations disparately, with low-income countries and vulnerable groups within them bearing a greater burden of climate-induced loss and damage.
  - Globally, a small fraction of households, comprising the **top 10 percent** with the highest per capita emissions, account for **34–45 percent of total household greenhouse** gas emissions, while the **bottom 50 percent contribute only 13–15 percent.**
- **Intergenerational Inequity:** Children and young people bear the brunt of climate change impacts despite having made minimal contributions to the crisis.
  - As they grow older, they will face increasingly severe consequences.
  - It is imperative to prioritize their rights in all climate-related decision-making and actions to address the injustices inherited from previous generations.

Carbon Inequality

Carbon inequality refers to the highly uneven distribution of carbon emissions worldwide. The wealthiest individuals emit unsustainable levels of carbon, with a significant portion of their emissions stemming from investments.

- According to Oxfam, **50% to 70%** of emissions from the **world's richest** individuals result from their investments.
- The **bottom 50%** of households contribute only **12%** of global greenhouse gas emissions, while the **top 1%** accounts for **17%**.

Types of Inequalities

- **Carbon Inequality Between Nations**: Developed countries emit a disproportionately high share of global CO_2 emissions.
- **Carbon Inequality within Nations:** Higher-income groups exhibit significantly higher carbon emissions.

Significance of Addressing Climate Inequality

- Acknowledges historical responsibilities.
- Mitigates social and economic disparities.
- Facilitates the design of effective, targeted climate policies.
- Maximizes the productive use of public investment.

Way Forward:

- Implement comprehensive tracking of individual emissions within countries.
- Enact policy instruments targeting investments in polluting and fossil fuel activities.
- Increase public investments in low-carbon energy production, transportation, and energy efficiency.
- Allocate significant resources to the production and collection of climate inequality statistics globally.

Tuvalu minister stands in sea to film COP26 speech to show climate change

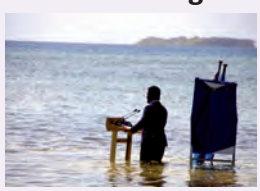


Fig. 12.25: Symbolism to draw attention to climate vulnerabilities.

The foreign minister of Tuvalu delivered a speech at the United Nations climate conference in Glasgow while standing in knee-deep seawater, symbolizing the urgent challenges his low-lying Pacific island nation faces due to climate change. This statement contrasts the formal setting of COP26 with the tangible realities experienced in Tuvalu, emphasizing the bold measures the nation is undertaking to confront pressing issues such as human displacement resulting from climate change.

Importance of Climate Justice

- Climate justice, in relation to the principle of **Common But Differentiated Responsibilities and Respective Capabilities(CBDR-RC),** highlights the need for developed nations to take greater responsibility for climate change due to **historical** emissions. It emphasizes equity in reducing emissions and providing support to vulnerable communities in developing countries.
- Climate change represents a **human rights issue**, with the fundamental principle that all individuals should have the ability to live their lives with dignity. However, the climate crisis is leading to loss of lives, livelihoods, languages, and cultures, exacerbating risks of food and water shortages, and inciting displacement and conflict.
- Furthermore, the climate crisis undermines the **right to good health**, with rising temperatures, more frequent extreme weather events, and polluted air and water resulting in significant health consequences such as heat stress, disease outbreaks, malnutrition, and trauma from disasters.
- These impacts are particularly severe for **vulnerable populations** who lack adequate resources to adapt to climate change. Between 2010 and 2020, **regions highly vulnerable** to floods, droughts, and storms experienced human **mortality rates 15 times higher** than regions with very **low vulnerability**.

Currently, those who have made the **smallest contributions to the climate crisis are bearing the greatest burden of its impacts**. Climate justice advocates for the allocation of responsibilities in addressing climate change based on the level of contribution, while also addressing systemic, socioeconomic, and intergenerational inequalities.

Obstacles to Climate Justice

Numerous challenges hinder countries and communities in their pursuit of climate justice.

- One challenge is the **lack of transparency and inclusivity** in climate negotiations and strategies. The voices of women, youth, Indigenous Peoples, and marginalized groups are crucial for shaping the planet's future.
  - It is imperative that they have access to decision-making platforms. However, these underrepresented voices may encounter **"tokenism,"** where they are included superficially **without genuine empowerment** or significant roles.
- Another barrier is the **limited access to education** and **resources** on environmental issues, climate change, and human rights.
  - This hampers the ability of those most affected by climate change from engaging in relevant policy discussions.

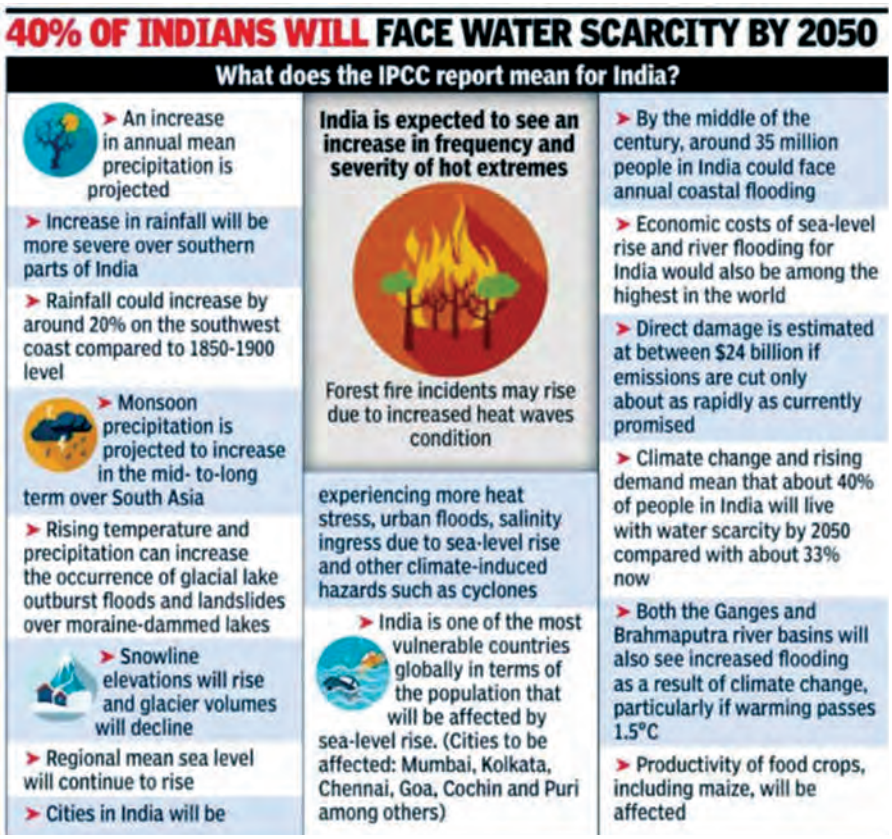

40% OF INDIANS WILL FACE WATER SCARCITY BY 2050
What does the IPCC report mean for India?
An increase in annual mean precipitation is projected
Increase in rainfall will be more severe over southern parts of India
Rainfall could increase by around 20% on the southwest coast compared to 1850-1900 level
Monsoon precipitation is projected to increase in the mid- to-long term over South Asia
Rising temperature and precipitation can increase the occurrence of glacial lake outburst floods and landslides over moraine-dammed lakes
Snowline elevations will rise and glacier volumes will decline
Regional mean sea level will continue to rise
Cities in India will be
India is expected to see an increase in frequency and severity of hot extremes
Forest fire incidents may rise due to increased heat waves condition
experiencing more heat stress, urban floods, salinity ingress due to sea-level rise and other climate-induced hazards such as cyclones
India is one of the most vulnerable countries globally in terms of the population that will be affected by sea-level rise. (Cities to be affected: Mumbai, Kolkata, Chennai, Goa, Cochin and Puri among others)
By the middle of the century, around 35 million people in India could face annual coastal flooding
Economic costs of sea-level rise and river flooding for India would also be among the highest in the world
Direct damage is estimated at between $24 billion if emissions are cut only about as rapidly as currently promised
Climate change and rising demand mean that about 40% of people in India will live with water scarcity by 2050 compared with about 33% now
Both the Ganges and Brahmaputra river basins will also see increased flooding as a result of climate change, particularly if warming passes 1.5°C
Productivity of food crops, including maize, will be affected

Fig 12.26: IPCC AR6 Synthesis Report

- **Language barriers** further exacerbate this challenge, particularly for **local** communities and **Indigenous Peoples** participating in decision-making processes.

- In numerous countries, **environmental activists** and defenders face perilous consequences for advocating for environmental rights and justice.
  - They often endure imprisonment, threats, violence, forced disappearances, or even death. This hostile environment discourages defenders from demanding justice.
- On a global scale, vulnerable countries have long been urging richer nations to provide more financial and technical assistance.
  - While there has been some recent progress in potential finance for loss and damage, many estimates suggest that **affluent countries have yet to meet the $100 billion annual climate finance commitment agreed upon in 2009.** This commitment was expected to commence in 2020.
  - Countries are currently deliberating a new annual target, as the existing one is insufficient and not aligned with scientific recommendations. Increased annual financing is imperative to address escalating global warming.

INITIATIVES AND CONTEMPORARY EVENTS

1. IPCC's Sixth Assessment-Synthesis Report

The Synthesis Report consolidates the primary discoveries of the AR6 cycle, drawing from inputs provided by the three Working Groups and the three Special Reports. Essential findings include:

- **Unprecedented Climate Warming:** Human-induced global warming of 1.1 degrees Celsius has instigated unparalleled alterations to Earth's climate in recent human history.
- Presently, with a global temperature increase of 1.1 degrees Celsius, the climate system is undergoing unparalleled changes across all global regions. These encompass rising sea levels, heightened extreme weather occurrences, and swiftly receding sea ice.
- **Broader Climate Influence:** The repercussions of climate change on both human populations and ecosystems surpass initial expectations in terms of scope and severity. Additionally, future risks are predicted to surge rapidly with each incremental temperature rise.
- **Adaptation Measures:** While adaptation measures can effectively enhance resilience, there is a need for increased financial support to scale up these solutions.

- While adaptation considerations are now integrated into climate policies in around 170 countries, numerous nations have not yet progressed from planning to execution.
- The resilience-building initiatives currently in place are mostly limited in scale, reactionary, and incremental, focusing primarily on immediate or short-term risks.
- The current allocation of global financial resources for adaptation is insufficient, posing constraints on the implementation of adaptation measures, especially in developing countries.

- **Global Temperature may Surpass 1.5 degrees Celsius:** According to various scenarios examined, there is a likelihood greater than 50% that global temperature will increase to or surpass 1.5 degrees Celsius between 2021 and 2040. In a high-emissions trajectory, the world might reach this threshold even earlier, possibly between 2018 and 2037.
- **Maladaptation**: Maladaptation refers to changes in natural or human systems that inadvertently heighten vulnerability to climate-related stimuli. It encompasses adaptation measures that fail to reduce vulnerability but instead exacerbate it.

2. Methane Emissions and Global Warming

Methane, a powerful greenhouse gas, has been responsible for about 30% of the global warming observed since the Industrial Revolution. Initiatives aimed at reducing methane emissions could potentially prevent around 0.1°C of warming by 2050.

Current Methane Emission Scenario

- Annually, around 580 million tonnes of methane are emitted globally.
- In 2022, fossil fuel operations alone emitted approximately 120 million tonnes of methane.
- In the present scenario, the overall anthropogenic methane emissions could rise by up to 13% between 2020 and 2030.

Need for Targeted Methane Mitigation

- Failure to address methane emissions could result in global temperatures exceeding 1.6°C by 2050, even with significant reductions in fossil fuel usage.
- Focused efforts to mitigate methane emissions are crucial and should complement decarbonization endeavors.
- Existing technologies have the potential to prevent over 80 million tonnes of annual methane emissions from fossil fuels by 2030, often with minimal or negative costs.
- An estimated USD 75 billion will be needed by 2030 to implement all methane reduction measures in the oil and gas sector under the Net Zero scenario.
- Actions such as eliminating routine venting and flaring and repairing leaks are essential for reducing methane emissions from the energy sector, highlighting the necessity of suitable regulatory frameworks.

Economic and Health Benefits

- Methane significantly contributes to ground-level ozone pollution, and efforts to mitigate it could potentially save nearly one million lives by 2050.
- Meeting methane reduction goals would prevent crop losses totaling **95 million tonnes** for major crops such as wheat, rice, soy, and maize, equivalent to approximately **60% of Africa's 2021 production** volume.
- Preventing these losses in crops, labor and forestry could result in direct economic gains valued at over USD 260 billion between 2020 and 2050.

3. Green Credit Initiative

Prime Minister Modi Unveils Innovative Climate Action Plan at COP 28:

- **Incentivizing Green Choices:** PM Modi launched the Green Credit Initiative, a bold new program at COP 28 to combat climate change. This initiative encourages individuals and organizations to take voluntary pro-environmental actions in exchange for "Green Credits."
- **Restoring Ecosystems:** Green Credits are issued for planting trees on degraded lands and near rivers, aiming to revitalize natural ecosystems and improve environmental health.
- **Global Collaboration:** The initiative fosters international cooperation by sharing knowledge, experiences, and best practices for implementing effective environmental programs like Green Credits.

4. India's Green Credit Program (GCP)

India's GCP is aimed at rewarding green actions:

- The GCP operates as a market-driven scheme to motivate people from various groups, including individuals, communities, and private enterprises, to undertake environmentally positive actions across diverse sectors.
- Announced in the 2023-24 Union Budget, it was officially launched by the Ministry of Environment in October 2023.
- Similar to existing carbon credit systems on national and international levels, where companies earn credits for reducing their carbon footprint, the GCP aims to replicate this model for broader environmental activities like water preservation and forest restoration.
- Initially, the program focuses on two crucial areas: water conservation and afforestation.
- Private companies can acquire these Green Credits to fulfill their Corporate Social Responsibility (CSR) commitments.
- The Indian Council of Forestry Research and Education (ICFRE) serves as the program's administrator.

IGNITE YOUR MIND

Sustainable Choices for Everyday Heroes:

Every choice we make can impact the web of life. Uncover how everyday choices like using reusable bags or reducing your carbon footprint can make a difference. How can you become a champion for sustainable living and inspire others to join the movement?

5. The Global Stocktake Report

The Global Stocktake, established under the Paris Agreement in 2015, is a **periodic review** mechanism occurring every five years.

- The **inaugural stocktake**, set to conclude at **COP28** in 2023, aims to evaluate countries' efforts in reducing greenhouse gas emissions and transitioning to renewable energy sources. It serves to hold nations accountable and push for increased climate ambitions.
- In 2015, as part of the Paris Agreement, countries committed to keeping global temperature increases below 2 degrees Celsius and ideally below 1.5 degrees Celsius by century's end, with periodic reviews of individual countries' efforts.
- The UNFCCC released the synthesis report of the inaugural Global Stocktake ahead of the **18th G20 summit** in New Delhi, outlining 17 significant findings that underscore a lack of advancement towards Paris Agreement objectives.
- With a limited timeframe for corrective actions, the report underscores the critical necessity for intensified global efforts.

Recommendations from the Report

- The Paris Agreement has spurred countries to set goals and underscore the urgency of the climate crisis. Governments should aid the transition away from fossil fuels, emphasizing equitable and inclusive economic shifts.
- More ambitious actions are imperative to reduce global greenhouse gas emissions by 43% by 2030 and 60% by 2035, aiming for net zero CO_2 emissions by 2050. Rapid changes must prioritize fairness and inclusivity.
- Scaling up renewable energy is crucial, alongside the swift elimination of unabated fossil fuels. Efforts to halt deforestation, promote sustainable agricultural practices, and conserve carbon sinks are essential.

GLOBAL STOCKTAKE
It is essentially a periodic review of global climate action which aims to assess whether current efforts will enable us to reach the objectives set out in the Paris Agreement.
2023 is the year for the Global Stocktake. This is the first Global Stocktake year since the Paris Agreement was signed in 2015 and the report has been underway for the past two years.
It is set to be released in September of 2023.
Talanoa dialogue IPCC 1.5°C Report
2018
2019
Article 6 Negotiations
Adoption of the Rulebook
2020
NDC
2023
1st GLOBAL STOCKTAKE
2025
NDC
2028
2nd GLOBAL STOCKTAKE
2030
NDC
2050
Carbon neutrality + Climate resilience

Fig 12.27: Global Stocktake

- Adaptation efforts are often fragmented and unequally distributed. Transparent reporting on adaptation measures could enhance understanding and international cooperation.
- Urgent action is needed to avert, minimize, and address loss and damage from climate change. Adequate support and funding for adaptation measures are crucial, requiring innovative and expanded sources.
- Climate finance access must be enhanced to align with resilient development goals. A significant shift in financial flows is necessary to support low-emission and climate-resilient development

Impact of the Report

- The Global Stocktake report had a significant influence on the **G20 Leaders Declaration**, a pivotal outcome of the summit.
- For the first time, the declaration recognized the substantial financial requirements linked to the shift towards renewable energy.
- It emphasized the need for USD 5.8-5.9 trillion in the pre-2030 period for developing countries and USD 4 trillion annually for clean energy technologies by 2030 to achieve Net-Zero emissions by 2050.

6. UN Ocean Conference (UNOC)

UN Ocean Conference 2022 was organised to ensure Ocean Ecosystem Protection and Sustainability. Co-hosted by the Governments of Kenya and Portugal, the Conference aimed to foster global cooperation in safeguarding and nurturing the world's ocean ecosystem. The Indian delegation, led by the Minister of Earth Sciences and and pledged to contribute science and innovation-driven solutions to advance Goal 14 of the Sustainable Development Goals (SDGs), focusing on "life below water," through collaborative partnerships and environmentally-friendly approaches.

Key Agenda of the Conference

- **Moratorium on Deep Sea Mining:** One of the primary agenda items was **advocating** for a moratorium on deep-sea mining activities targeting rare metals crucial for electric vehicle battery production. Concerns were raised over the potential ecological impact of **ocean floor excavation**, which could disrupt or destroy **deep-sea habitats**.
- **Carbon Sequestration:** Another focal point was carbon sequestration initiatives aimed at enhancing the **ocean's capacity** to absorb CO_2. Strategies discussed included bolstering natural carbon sinks like **mangroves** and exploring **geoengineering techniques**.
- **Blue Deal:** The promotion of a "Blue Deal" emerged as a central theme, emphasizing the sustainable utilization of ocean resources to foster economic growth.

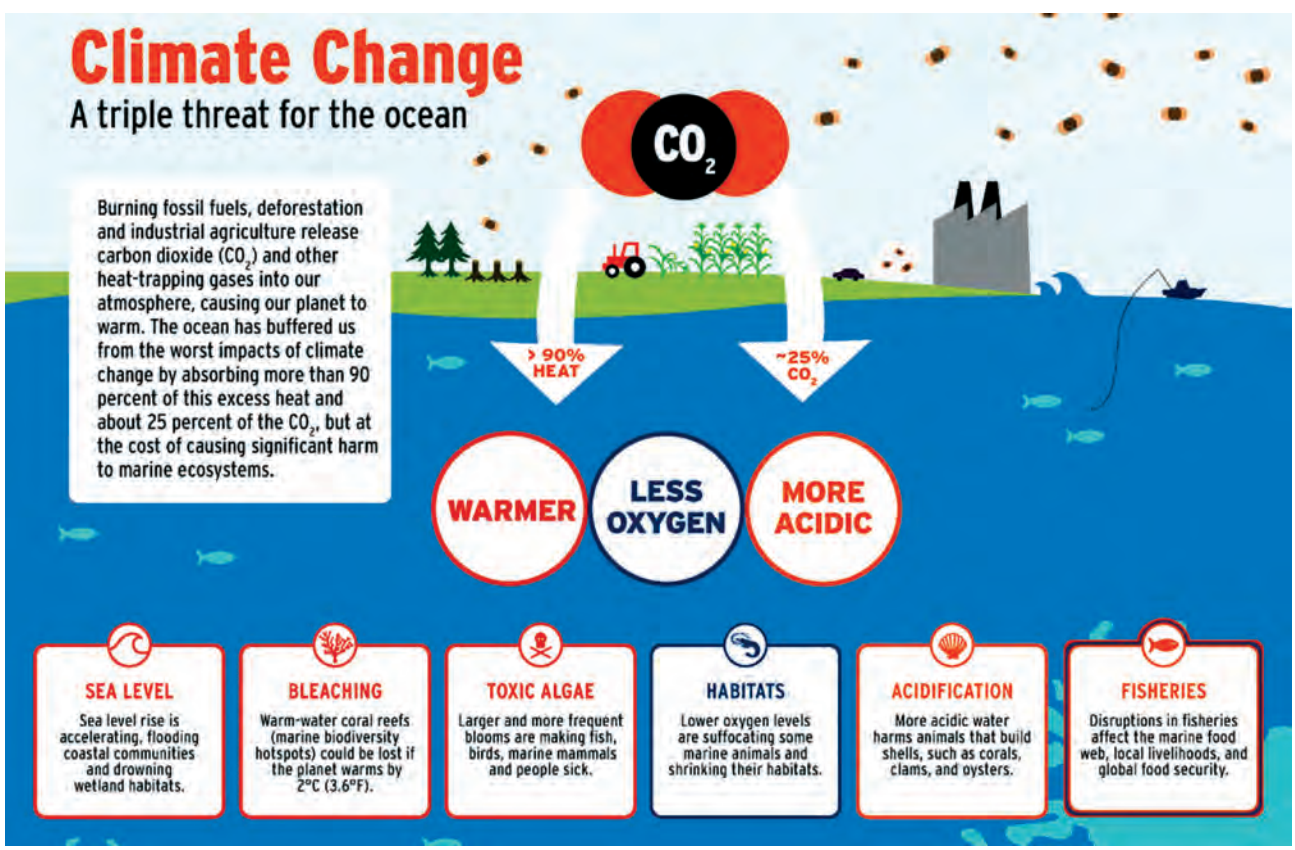

Climate Change
A triple threat for the ocean
CO2
Burning fossil fuels, deforestation and industrial agriculture release carbon dioxide (CO2) and other heat-trapping gases into our atmosphere, causing our planet to warm. The ocean has buffered us from the worst impacts of climate change by absorbing more than 90 percent of this excess heat and about 25 percent of the CO2, but at the cost of causing significant harm to marine ecosystems.
> 90% HEAT
~25% CO2
WARMER
LESS OXYGEN
MORE ACIDIC
SEA LEVEL
Sea level rise is accelerating, flooding coastal communities and drowning wetland habitats.
BLEACHING
Warm-water coral reefs (marine biodiversity hotspots) could be lost if the planet warms by 2°C (3.6°F).
TOXIC ALGAE
Larger and more frequent blooms are making fish, birds, marine mammals and people sick.
HABITATS
Lower oxygen levels are suffocating some marine animals and shrinking their habitats.
ACIDIFICATION
More acidic water harms animals that build shells, such as corals, clams, and oysters.
FISHERIES
Disruptions in fisheries affect the marine food web, local livelihoods, and global food security.

Fig 12.28: Climate Change: A triple threat for the Ocean

- This comprehensive framework encompasses global trade, investment, and innovation to foster a resilient and sustainable ocean economy.
- Special emphasis was placed on promoting sustainable and socially responsible practices in marine food production, known as "**blue food**."

❑ **Challenges in Regulating High Seas:** The conference highlighted the regulatory gaps concerning the high seas, which cover approximately **70%** of the Earth's surface and support billions of people with food and livelihoods. Activists raised concerns over the lack of a comprehensive legal framework, labeling the high seas as the biggest non-regulated area on the planet.

❑ **Threats to Ocean Health:** Various potential hazards to ocean health, including global warming, pollution (especially plastic pollution), acidification, and marine heatwaves, were underscored during the conference, emphasizing the urgent need for concerted action to address these challenges.

7. Innovation Roadmap of the Mission Integrated Biorefineries (IRMIB)

The Government of India has announced the launch of the "Innovation Roadmap for the Mission Integrated Biorefineries" at the Global Clean Energy Action Forum in **Pittsburgh, United States.**

❑ Launched in **collaboration** with **Brazil, Canada, the European Commission (EC), and the United Kingdom (UK)**, the roadmap aims to address gaps and challenges in current biorefining value chains. It prioritizes eight key actions to support the Mission and guide its path towards achieving its goals.

❑ The roadmap also offers policymakers a strategic framework for establishing a robust research and development (R&D) portfolio over the next five years. It includes specific financing proposals for vital biorefinery technologies and rapid action suggestions.

The Integrated Biorefineries Mission: It was co-led by **India and the Netherlands,** aims to develop and demonstrate innovative solutions to accelerate the commercialization of integrated biorefineries. Its target is to **replace 10% of fossil-based fuels, chemicals, and materials** with bio-based alternatives by 2030.

8. Carbon Border Adjustment Mechanism (CBAM)

❑ **Implementation:** Under the "**Fit for 55 in 2030 package**," the Carbon Border Adjustment Mechanism (CBAM) will play a crucial role in reducing greenhouse gas emissions by a minimum of **55% by 2030 compared to 1990 levels**, aligning with the **European Climate Law**. It functions as a policy instrument to curb carbon emissions by ensuring that imported goods carry the same carbon costs as products manufactured within the EU.

❑ **Enforcement:** CBAM will be enforced by mandating importers to disclose the quantity of goods brought into the EU along with their embedded greenhouse gas (GHG) emissions on an annual basis. Importers will be required to offset these emissions by surrendering a corresponding number of CBAM certificates, with prices determined by the weekly average auction price of EU Emission Trading System (ETS) allowances in euros per tonne of CO_2 emitted.

❑ **Commencement and Tax Rates:** The European Union (EU) has announced the phased introduction of its Carbon Border Adjustment Mechanism **(CBAM)** beginning in October 2023. Initially, this mechanism will impose a carbon tax on imports of products manufactured using processes deemed environmentally unsustainable or non-green. From **January 1, 2026**, CBAM will **impose a tax ranging from 20% to 35% on selected imports** into the EU.

Objectives

CBAM aims to prevent climate objectives from being undermined by carbon-intensive imports and to promote cleaner production practices worldwide.

Significance

❑ CBAM may encourage non-EU countries to adopt more stringent environmental regulations, thereby reducing global carbon emissions.

❑ It can help alleviate carbon leakage by discouraging companies from relocating to countries with lax environmental regulations.

❑ Revenue generated from CBAM will support EU climate policies and could serve as a model for other countries seeking to promote renewable energy.

IGNITE YOUR MIND

Bordering on Change: The Carbon Border Adjustment Mechanism is like a climate border patrol, ensuring polluters pay their fair share. Will this mechanism foster international cooperation, or spark trade wars that hinder progress?

9. The Global Cooling Watch 2023 Report

The Global Cooling Watch 2023 Report, titled "**Keeping it Chill: Meeting Cooling Demands while Reducing Emissions**," was published by the **UN Environment Programme (UNEP)-led Cool Coalition.** It supports the **Global Cooling Pledge**, initiated at **COP28**, aiming to address the rising demand for cooling while mitigating its climate impacts. While 63 countries have signed the pledge, India has not signed it yet. The report offers a comprehensive analysis of the global cooling sector, encompassing space cooling and cold chains for food and health. Key highlights include:

- Cooling equipment presently consumes 20% of total electricity and is projected to more than double by 2050.
- Without intervention, emissions from cooling are forecasted to exceed 10% of global emissions by 2050.
- The report advocates for sustainable cooling through passive cooling, higher energy efficiency standards, and accelerated phase-out of climate-warming HFC refrigerants under the Kigali Amendment to the Montreal Protocol.
- These measures could potentially reduce sectoral emissions by 60% by 2050.

10. UNDP Launches National Carbon Registry

UNDP has developed an **open-source software** which allows countries to effectively manage national data and processes for trading carbon credits.

- The software, called the **National Carbon Registry**, has recently been accredited as a **digital public good (DPG).**
  - As a DPG, the registry uses **open-source code**, which allows countries to replicate and adapt the information to fit their own needs and contexts.
- The registry's modules, software and technical documentation **can be reused and tailored by countries**, which could potentially **reduce production costs and implementation timelines.**
- One of the key strengths of the National Carbon Registry is its adherence to national and international best practices.
  - It has been developed in collaboration with various organizations, including **UNDP, the World Bank, the United Nations Framework Convention on Climate Change (UNFCCC), and the European Bank for Reconstruction and Development (EBRD).**
  - This collaborative effort ensures that the software incorporates the latest insights and expertise, making it a reliable tool for managing carbon credits.

Benefits for India

- **Carbon Credit Management:** It serves as a robust tool for streamlining the management of carbon credits, offering efficiency in tracking, verification, and trading.
- **Tracking Nationally Determined Contributions:** This technology can aid India in meeting its Nationally Determined Contributions (NDCs) and reinforcing its climate action efforts.
- **Cost efficiency:** Moreover, India can realise cost-efficiency by customising the National Carbon Registry to its specific needs through the use of open-source technology.

This adaptability can potentially reduce the expenses associated with developing and maintaining carbon credit registries, a particularly important aspect for nations with limited resources.

11. Technical Report on the Global Stocktake

About Global Stocktake (GST)

- Held **every five years,** the GST is a process for countries to assess where they are collectively making progress towards meeting the climate goals, and where they are not.
- Two UN reports released ahead of COP28 will inform the political outcome of the GST.
  - **Synthesis report:** It is designed to **help countries reach a decision on the global stocktake at COP28**, it reflects the **views of governments** on the main elements that could form part of the political outcome.
  - **Technical report:** The most extensive review of climate action to date, which sets out **actionable solutions** to climate change that are ready to be implemented.
- These reports will inform the next round of climate action plans (nationally determined contributions, or 'NDCs') under the Paris Agreement that countries should submit in 2025.

Key Findings of the Reports

- **Emissions Gap:** The current pledges are insufficient to meet climate goals, falling short by 20-23 Gt CO_2 equivalent compared to 1.5°C target by 2030.
- **Global Reductions Needed:** Must cut emissions by 43% by 2030 and 60% by 2035 (from 2019 levels) to reach net-zero CO_2 by 2050. Requires transformation in all sectors.
- **Adaptation Urgency:** Adaptation is no longer optional due to intensifying climate impacts, especially for vulnerable communities. Every fraction of a degree warming matters, with irreversible effects beyond 1.5°C.
- **Finance and Technology:** Finance, technology, and capacity building are crucial for effective action. The international financial system needs reform to support low-emission development and mobilize support for developing countries.
- **Historical Emissions:** Developed countries' historical and current emissions are acknowledged as a key issue, vital for building trust and ensuring equitable contributions.
- **Clean Technology Focus:** Deployment and innovation in clean technologies are crucial, especially for supporting developing countries. Collaborative research and development are essential.

12. New York Declaration on Forests

- The New York Declaration on Forests (NYDF), endorsed during the **United Nations Climate Summit in September 2014**, highlights ten objectives, notably aiming to halt natural forest loss by 2030.

- Additionally, it targets the restoration of 350 million hectares of degraded landscapes and forestlands, enhancing governance, boosting forest finance, and reducing emissions from deforestation and forest degradation, all within the framework of a post-2020 global climate agreement.
- As a voluntary and non-binding international declaration, the NYDF emphasizes collective efforts to combat global deforestation.
- With endorsements from over 200 entities, including national and subnational governments, companies, indigenous groups, financial institutions, and NGOs, the declaration receives support for achieving its objectives and implementing its accompanying action plan. Currently, India has not ratified the New York Declaration on Forests (NYDF).

13. Global Climate Change Alliance

- It is an initiative of the **European Union.**
- It provides technical and financial support to targeted developing countries to integrate climate change into their development policies and budgets.

14. Climate and Clean Air Coalition

- It is a voluntary partnership of over 160 governments, intergovernmental organizations, and non-governmental organizations.
- The CCAC works to reduce powerful but **short-lived climate pollutants (SLCPs)** – methane, black carbon, hydrofluorocarbons (HFCs), and tropospheric ozone – that drive both climate change and air pollution.
- It aims to stimulate fresh initiatives while also emphasizing and reinforcing existing endeavors concerning immediate climate change challenges, along with associated issues pertaining to public health, food and energy security, and environmental concerns.
- India has officially joined the **Climate & Clean Air Coalition (CCAC),** becoming the 65th nation to do so.

15. The Climate Action Tracker

- The Climate Action Tracker, an independent scientific analysis initiated in 2009, is a collaborative effort between two research organizations, Climate Analytics and New Climate Institute.
- It evaluates government climate action against the objectives outlined in the Paris Agreement, aiming to limit global warming to "well below 2°C" and striving for a 1.5°C target. This initiative monitors 32 countries, representing over 80 percent of global emissions, providing policymakers with impartial assessments of climate progress.

16. Global Maritime Energy Efficiency Partnership (GloMEEP)

GloMEEP, a project by **GEF-UNDP-IMO**, aims to promote and implement energy efficiency measures in shipping to reduce greenhouse gas emissions.

- The project is managed by a dedicated Project Coordination Unit (PCU) within IMO's Marine Environment Division, responsible for ensuring safe, secure, and efficient shipping and pollution prevention from ships.
- GloMEEP assists **Ten Lead Pilot Countries** (LPCs) in implementing these measures through legal, policy, and institutional reforms, awareness-raising activities, capacity-building initiatives, and fostering public-private partnerships for technology transfer.
- The LPCs include Argentina, China, Georgia, India, Jamaica, Malaysia, Morocco, Panama, the Philippines, and South Africa.

17. Adaptation for Smallholder Agriculture Programme (ASAP)-IFAD

The ASAP, initiated by the International Fund for Agricultural Development (IFAD), directs climate finance towards smallholder farmers.

- Its aim is to provide them with tools and technologies to enhance their resilience to climate change.
- ASAP stands as the **world's largest** climate change adaptation initiative for **smallholder farmers,** benefitting millions of them globally.

IGNITE YOUR MIND

Adapting to Change: The climate is changing, and you're tasked with building a metaphorical ark for human society. What adaptation strategies will you use to ensure communities can weather the storms of climate change, from rising sea levels to extreme weather events?

18. Artificial Intelligence for Agriculture Innovation" (AI4AI) initiative

The vision of AI4AI is to revolutionize agriculture by integrating emerging technologies in an inclusive and sustainable manner. It aims to develop scalable frameworks to harness these technologies for positive outcomes while addressing challenges and potential drawbacks.

- While prioritizing technological innovation, the program emphasizes the importance of investing in low-tech solutions, implementing progressive policies, optimizing resource utilization, fostering trust and transparency, aligning efforts towards common goals, and fostering collaboration among independent working groups.

- The key objectives of AI4AI include enhancing digital and financial inclusion for smallholder farmers, ensuring trust and transparency through quality and traceability, promoting environmental sustainability, and establishing resilient farm incomes.
- Under the guidance of the World Economic Forum (WEF) as part of the AI4AI initiative, **Telangana's "Saagu Baagu"** pilot project has positively influenced the lives of more than 7,000 **chilli farmers** in the state, fostering agricultural advancement.

INTERNATIONAL ORGANIZATIONS

1. United Nations Environment Programme (UNEP)

The United Nations Environment Programme (UNEP) is a specialized agency of the United Nations responsible for coordinating global environmental activities.

- **Headquarters:** Nairobi, Kenya
- **Formation/Inception:** It was established on December 15, 1972, following the United Nations Conference on the Human Environment held in Stockholm, Sweden. It was created in response to growing concerns about environmental degradation and the need for international cooperation
- **Mandate:** To provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.
- UNEP serves as the **home for the secretariats** of several important **conventions**, including: Minamata Convention, United Nations Convention on Biological Diversity, Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Basel Convention, Stockholm Convention, Rotterdam Convention, Montreal Protocol, Vienna Convention, Convention on Migratory Species, Tehran Convention, Bamako Convention, Carpathian Convention, Climate & Clean Air Coalition (CCAC).
- **Important programmes of UNEP: Earth Hour, Clean up the World, Billion Tree Campaign, Seal the Deal, Pain for the Planet, Awareness and Preparedness for Emergencies at Local Level (APELL), TUNZA, Faith for Earth**
- The United Nations Environment Assembly is the governing body of UNEP with 193 countries(all UN members).
- **Reports by UNEP**: Emissions Gap Report, Global Cooling Watch, Adaptation Gap Report, Renewable Energy and Sustainability Report, Faith for Earth: Achievement Report, Global Cooling Pledge, International Methane Emissions Observatory Report, Production Gap Report.

Initiatives and Events Associated with UNEP

- **Colombo Declaration:** With technical assistance from the International Nitrogen Management System (INMS), a collaboration between UNEP and the International Nitrogen Initiative backed by the Global Environmental Facility, the Colombo Declaration has been crafted.
  - Its objective is to reduce nitrogen waste by 50% by 2030. Additionally, a campaign named "**Nitrogen for Life**" is slated for launch, stemming from the Sustainable Nitrogen Management Resolution endorsed during the fourth session of the UN Environment Assembly held from March 11 to 15, 2019, at the UNEP headquarters in Nairobi, Kenya.
- **Bonn Convention:** Signed in 1979, the **Convention on Migratory Species (CMS)**, also known as the Bonn Convention, operates as an intergovernmental treaty under UNEP. It has been in effect since 1983 and counts 133 Parties, including India since 1983.
  - **Objective and Legal Framework:** The primary goal of the CMS is to conserve terrestrial, marine, and avian migratory species across their habitats, providing a legal framework for global conservation efforts.
    - The convention employs various legal instruments, from binding Agreements to less formal Memorandum of Understanding (MoUs), and includes two appendices:
      - Appendix I, listing 'Threatened Migratory Species', and
      - Appendix II, listing 'Migratory Species requiring international cooperation'.
  - **India's Engagement:** India's involvement with the CMS primarily revolves around non-binding MoUs focusing on the conservation and management of Siberian Cranes (1998), Marine Turtles (2007), Dugongs (2008), and Raptors (2016).
    - Despite covering only **2.4% of the world's land area**, India hosts around **8%** of the known global biodiversity and serves as temporary shelter to various migratory species, including Amur Falcons, Bar-headed Geese, Black-necked Cranes, Marine Turtles, Dugongs, and Humpback Whales.
- **Global Alliance to Eliminate Lead Paint:** The Lead Paint Alliance, a collaborative initiative between the United Nations Environment Programme **(UNEP)** and the World Health Organization **(WHO),** is dedicated to eradicating lead exposure by advocating for the elimination of lead-containing paints.
- **International Cyanide Management Code:** The "Cyanide Code," formulated by a diverse steering committee under the auspices of the United Nations Environmental Program (UNEP) and the International Council on Metals and the Environment (ICME), is a voluntary initiative tailored to the mining sector.

- Its primary aim is to elevate the standards for handling cyanide in gold and silver extraction processes, thereby bolstering human health safeguards and mitigating environmental repercussions.

- **World Adaptation Science Programme(WASP):** WASP, led by UNEP, WMO, UNFCCC, IPCC, GCF, GEF, UNU, and UNESCO, equips stakeholders with the necessary knowledge and solutions for effective climate change adaptation. Its primary goal is to support UNFCCC, IPCC, GCF, and GEF initiatives through tailored products and services.
- **Portfolio Carbon Initiative (PCI):** In collaboration with the **2 degrees Investing Initiative (2DII)** and the **UNEP Finance Initiative (UNEP FI)**, the Portfolio Carbon Initiative offers financial institutions guidance on evaluating the climate impact of their operations and carbon asset risk. Formerly known as the Financed Emissions Initiative, this effort provides resources to assist in these assessments.
- **UNEP: Global Programme of Action:** The Global Programme of Action (GPA) is the sole worldwide intergovernmental initiative specifically targeting the interlinkages among terrestrial, freshwater, coastal, and marine ecosystems.
  - Its objective is to serve as both a conceptual and practical resource for national and regional authorities, aiding them in developing and executing ongoing efforts to prevent, diminish, regulate, or eliminate marine degradation stemming from activities on land.

2. Intergovernmental Panel on Climate Change (IPCC)

- **Headquarters:** Geneva, Switzerland
- **Formation/Inception:** IPCC was established in **1988** by the World Meteorological Organization (**WMO**) and the United Nations Environment Programme (**UNEP**).
- **Mandate:** To assess the science related to climate change and provide governments worldwide with scientific information to aid in the development of climate policies.
- The IPCC issues regular assessment reports, compiled by global experts, providing authoritative information on climate change. These reports evaluate current scientific literature and cover topics including mitigation, adaptation, and sustainable development. Additionally, the IPCC releases special reports on specific issues within these areas.
- Recently, IPCC's 6th assessment report was released.
- The IPCC's **Fourth Assessment** Report, released in 2007, earned the organization the **Nobel Peace Prize**.
- The findings of the **First Assessment Report** contributed to the establishment of the UN Framework Convention on Climate Change(**UNFCCC**), which serves as the foundation for annual international climate change negotiations.
- The **Second Assessment** Report provided the basis for the development of the **Kyoto Protocol** in 1997.
- The **Fifth Assessment Report,** published in 2014, informed the negotiations leading to the **Paris Agreement.**
- **The Task Force on National Greenhouse Gas Inventories (TFI):** The Task Force on National Greenhouse Gas Inventories (TFI) is responsible for developing and enhancing a globally-accepted methodology and software to calculate and report national greenhouse gas (GHG) emissions and removals.

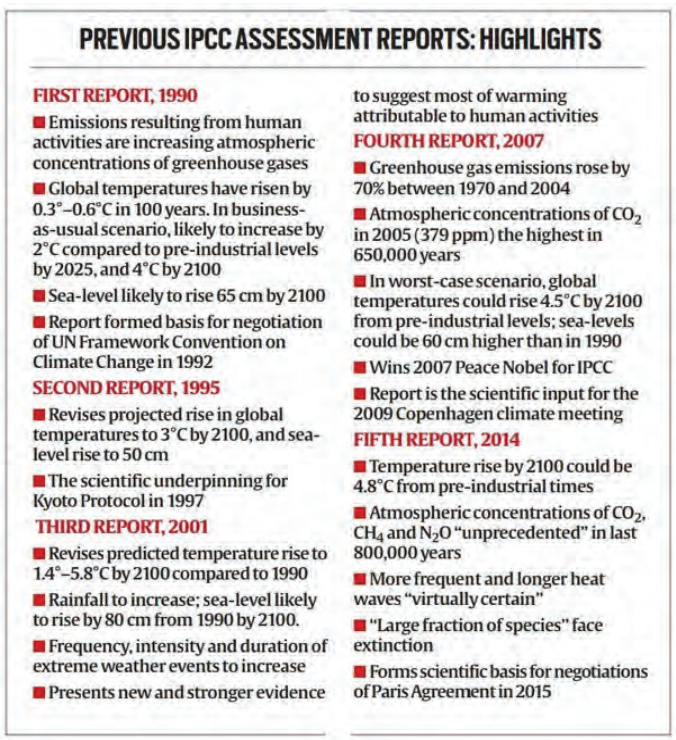

PREVIOUS IPCC ASSESSMENT REPORTS: HIGHLIGHTS
FIRST REPORT, 1990
Emissions resulting from human activities are increasing atmospheric concentrations of greenhouse gases
Global temperatures have risen by 0.3°–0.6°C in 100 years. In business-as-usual scenario, likely to increase by 2°C compared to pre-industrial levels by 2025, and 4°C by 2100
Sea-level likely to rise 65 cm by 2100
Report formed basis for negotiation of UN Framework Convention on Climate Change in 1992
SECOND REPORT, 1995
Revises projected rise in global temperatures to 3°C by 2100, and sea-level rise to 50 cm
The scientific underpinning for Kyoto Protocol in 1997
THIRD REPORT, 2001
Revises predicted temperature rise to 1.4°–5.8°C by 2100 compared to 1990
Rainfall to increase; sea-level likely to rise by 80 cm from 1990 by 2100.
Frequency, intensity and duration of extreme weather events to increase
Presents new and stronger evidence to suggest most of warming attributable to human activities
FOURTH REPORT, 2007
Greenhouse gas emissions rose by 70% between 1970 and 2004
Atmospheric concentrations of CO_2 in 2005 (379 ppm) the highest in 650,000 years
In worst-case scenario, global temperatures could rise 4.5°C by 2100 from pre-industrial levels; sea-levels could be 60 cm higher than in 1990
Wins 2007 Peace Nobel for IPCC
Report is the scientific input for the 2009 Copenhagen climate meeting
FIFTH REPORT, 2014
Temperature rise by 2100 could be 4.8°C from pre-industrial times
Atmospheric concentrations of CO_2, CH_4 and N_2O "unprecedented" in last 800,000 years
More frequent and longer heat waves "virtually certain"
"Large fraction of species" face extinction
Forms scientific basis for negotiations of Paris Agreement in 2015

Fig 12.30: Highlights of first five IPCC reports

- It promotes the adoption of this methodology among countries participating in the IPCC and those who are signatories to the United Nations Framework Convention on Climate Change (UNFCCC).

3. World Meteorological Organization (WMO)

- **Headquarters:** Geneva, Switzerland.
- The WMO was established in 1950 as a specialized agency of the United Nations.
- **Mandate:** Coordinating international cooperation in meteorology, climatology, hydrology, and related fields. Publishes reports and assessments of the state of the climate and weather forecasts.
- **Major initiatives: Integrated Global Observing System (IGOS), the World Climate Research Programme (WCRP), the World Weather Watch (WWW), and the Global Atmosphere Watch (GAW).**

- It serves as the definitive authority within the UN system regarding the condition and dynamics of the Earth's atmosphere, its interplay with the oceans, the climate it engenders, and the consequent allocation of water resources.

4. World Health Organization (WHO)

- **Headquarters and Formation:** The WHO is headquartered in **Geneva**, Switzerland, and was established on April 7, 1948, as a specialized agency of the United Nations.
- **Mandate:** Its mandate involves coordinating international public health efforts, setting norms and standards, providing technical support, and conducting research to improve global health outcomes.
- **Reports: World Health Report, Global Nutrition Report, World Vision Report, Ambient Air Pollution Report, World Report on Hearing**
- **Major Initiatives and Programs**: Global Polio Eradication Initiative, the Expanded Programme on Immunization, the Global Tuberculosis Programme, and the Framework Convention on Tobacco Control.
- It seeks to promote international collaboration to enhance public health conditions. Every year, WHO commemorates its founding date, April 7, 1948, as **World Health Day.**

5. International Union for Conservation of Nature (IUCN)

- The IUCN is an international organization that works in the field of conservation of the world's flora and fauna.
- The IUCN is a global union composed of **both government as well as civil society** organizations.
- More than **1400 organizations** are its members, making the IUCN an international authority on the status of the natural world.
- When it was **first set up in Fontainebleau** (France) in 1948, it was the first international environmental union. Its objective was to promote international cooperation and provide scientific knowledge and tools to aid conservation action.
- It established the **IUCN Red List** of Threatened Species in 1964.
- It also played a huge role in the formation of major international conventions such as: the Ramsar Convention on Wetlands, the Convention on International Trade in Endangered Species, the World Heritage Convention and the Convention on Biological Diversity.

IUCN Initiatives

- **Mangroves for the Future (MFF):** It is an initiative, developed by **IUCN** and **UNDP**, promotes investment in coastal ecosystem conservation. Member nations encompass Bangladesh, Cambodia, India, Indonesia, Maldives, Myanmar, Pakistan, Seychelles, Sri Lanka, Thailand and Vietnam.
- **World Commission on Protected Areas (WCPA)**: It is the leading global network of expertise on protected and conserved areas. With over 2500 members across 140 countries, the Commission offers strategic advice to policy-makers and endeavours to enhance capacity and investment for establishing and managing protected areas.
- **Asian Elephant Specialist Group (AsESG):** It operates within the Species Survival Commission (SSC) of the International Union for Conservation of Nature (IUCN).
  - Its mandate is to offer scientifically informed insights into the abundance, distribution, and demographic trends of Asian elephant populations across all 13 range states.
  - The group periodically compiles comprehensive assessments of the elephant's range, which are publicly shared through the AsESG website and other channels.

6. United Nations Development Programme (UNDP)

- **Headquarters:** New York City, United States.
- **Formation/Inception:** Established in 1965, UNDP was created through a merger of the Expanded Programme of Technical Assistance (EPTA) and the United Nations Special Fund.
- **Mandate**: UNDP's mandate revolves around eradicating poverty, reducing inequalities, and building resilience to crises and shocks. It aims to support countries in achieving sustainable development goals by providing technical expertise, promoting policy dialogue, and mobilizing resources.
- UNDP produces various reports, including the **Human Development Report** (HDR), which assesses global human development trends and challenges. Additionally, it publishes thematic reports on topics such as gender equality, climate change, and sustainable development.
- **UNDP's focus areas include:**
  - **Sustainable Development Goals (SDGs):** Addressing poverty, inequality, climate change, and environmental degradation globally.
  - **Climate Action:** Supporting countries in climate change adaptation, mitigation, and promoting renewable energy.
  - **Gender Equality:** Empowering women through economic, political, and social initiatives.
  - **Crisis Response and Recovery:** Assisting countries in rebuilding after conflicts, natural disasters, and humanitarian crises.
  - **Democratic Governance:** Promoting accountable and inclusive governance through reforms and capacity-building initiatives.

- **Small Grants Programme:** The Global Environment Facility's SGP offers financial and technical support to community-led projects conserving and restoring the environment while benefiting local communities.
  - Launched in 1992 by UNDP, it complements other GEF initiatives and has aided 136 countries.
  - Grants of up to $50,000 are provided directly to local communities, including indigenous peoples and NGOs, for projects addressing Biodiversity, Climate Change, Land Degradation, Sustainable Forest Management, International Waters, and Chemicals.

7. International Renewable Energy Agency (IRENA)

- **IRENA**, the International Renewable Energy Agency, is an intergovernmental organization dedicated to facilitating the transition to a sustainable energy future. It was officially founded in Bonn, Germany, in 2009. It has its headquarters in Abu Dhabi, United Arab Emirates
- It serves as a hub for international cooperation and knowledge exchange on renewable energy, supporting countries in adopting and utilizing renewable energy sources such as bioenergy, geothermal, hydropower, ocean, solar and wind energy.
- IRENA offers a range of services, including annual reviews of renewable energy employment, capacity statistics, cost studies and readiness assessments.
- It also provides tools like the Global Atlas for mapping resource potential, REmap for doubling renewable energy use by 2030, and project development support through initiatives like the Project Navigator and Sustainable Energy Marketplace.
- The idea for IRENA was first proposed in 1981 at the **United Nations Conference on New and Renewable Sources of Energy in Nairobi, Kenya.**
- Over the years, support for such an agency grew, culminating in its establishment following key meetings and conferences focused on renewable energy policies, financing, and technology, including the 2004 Bonn International Renewable Energy Conference.
- Today, with over 180 member countries, IRENA continues to promote renewable resources and technologies as essential components of a sustainable future.

8. Ramsar Convention on Wetlands

- The Convention on Wetlands (Ramsar, Iran, 1971) is an inter- governmental treaty whose mission is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world".
- Named after the **city of Ramsar in Iran,** where it was signed on **February 2, 1971,** the convention designates **February 2nd** each year as **World Wetlands Day.**
- With 171 parties to the convention, its **central philosophy** is the **"wise use"** of wetlands, which involves maintaining their ecological character while promoting sustainable development.
- The need for such a convention is underscored by the critical role wetlands play in providing various ecosystem services, including freshwater supply, biodiversity support, flood control, and climate change mitigation. Despite their importance, **64% of the world's wetlands** have **disappeared** since the beginning of the last century.
- Therefore, the Ramsar Convention serves as a crucial framework for addressing the conservation and sustainable management of these vital ecosystems.

Montreux Record: The Montreux Record serves as a registry for wetland sites listed as Wetlands of International Importance under the Ramsar Convention.

- It documents instances where alterations in ecological characteristics have taken place, are ongoing, or are anticipated due to factors such as technological advancements, pollution, or other human interventions.
- This record is an **integral component of the Ramsar List**, highlighting areas warranting special attention for conservation efforts.

9. Organization for Economic Co-operation and Development (OECD)

- The OECD, an international organization comprising 38 member countries, is dedicated to promoting democracy and free-market economies, with its **headquarters** in **Paris, France.**
- Its members are **typically democratic nations supporting market economies**. Established on December 14, 1960, by 18 European nations, the United States, and Canada, the OECD is headquartered in Paris, France.
- The stated **objective** of the Organisation for Economic Co-operation and Development (OECD) is to shape policies that advance prosperity, equality, opportunity, and well-being for all.
- It produces economic reports, statistical databases, analyses, and forecasts on global economic growth prospects. Additionally, the OECD works to **combat bribery and other financial crimes** worldwide and maintains a **"black list"** of nations deemed uncooperative tax havens.
- Apart from its member countries, the OECD **collaborates** with numerous **non-member economies like India**, fostering working relationships to achieve its objectives.

10. International Maritime Organization (IMO)

- The International Maritime Organization (IMO) functions as a specialized agency within the United Nations (UN) with its **headquarters** at **London.**
- As a global **standard-setting authority**, its primary **mandate** is to enhance the safety and security of international shipping while preventing marine and atmospheric pollution caused by ships.
- Although the IMO **does not enforce its policies directly,** it serves as the primary body responsible for developing regulatory frameworks that are equitable, effective, and universally accepted in the shipping industry.
- Additionally, the organization engages in legal matters, including issues related to liability, compensation, and the facilitation of international maritime traffic.
- Established through a Convention adopted under the United Nations in Geneva on March 6, 1948, the IMO convened for the first time in January 1959. Presently, it counts 176 Member States and 3 associate members among its ranks.

London Convention: The objective of the London Convention and London Protocol is to safeguard the marine environment from pollution resulting from the disposal of wastes and other materials into the ocean.

- Adopted in 1972 and enforced in 1975, the London Convention addresses this issue, while the London Protocol, established in 1996 and enforced in 2006, provides further guidelines.
- **India** has so far not ratified either of the conventions.

11. Food and Agriculture Organization (FAO)

The Food and Agriculture Organization (FAO) is a specialized agency of the United Nations dedicated to addressing global food security and promoting sustainable agriculture.

- **Establishment and Headquarters**: Established in 1945, the FAO is headquartered in Rome, Italy. It aims to ensure universal access to high-quality food and promote healthy lifestyles.
- **Membership and Conferences:** The FAO has 197 member countries, including the European Union. It conducts biennial conferences to address key issues in food security and agriculture.
- **Mission and Goals**: The FAO's primary goal is to achieve food security for all by providing regular access to nutritious food. It strives to improve nutrition and food security globally.
- **Key Reports and Publications**: The FAO publishes major reports on various topics, including food, agriculture, forestry, fisheries and natural resources. These include:
  - The State of the World's Forests (SOFO)
  - The State of World Fisheries and Aquaculture (SOFIA)
  - The State of Agricultural Commodity Markets (SOCO)
  - The State of Food Security and Nutrition in the World (SOFI)
  - Additionally, it oversees the implementation of the Joint FAO/WHO Food Standards Programme through the **Codex Alimentarius Commission.**
- **Initiatives and Programs**: The FAO is involved in various initiatives and programs, including the Agricultural Heritage Systems of Global Importance (**GIAHS**) and monitoring the **status of Desert Locusts** worldwide. It also adopted the **International Treaty on Plant Genetic Resources** for Food and Agriculture in 2001.
- **Collaboration and Partnerships:** The FAO works closely with sister bodies such as the World Food Programme (**WFP**) and the International Fund for Agricultural Development (**IFAD**) to address global food security challenges.
- **Forest and Landscape Restoration Mechanism(FLRM):** Established by the FAO, the FLRM seeks to enhance, monitor, and report on FLR initiatives to support the **Bonn Challenge** and **Aichi** Biodiversity targets.
  - It facilitates the coordination and implementation of projects and programs across FAO member countries, collaborating closely with other stakeholders.
  - Operating on a global scale, the FLRM focuses on financial intelligence activities such as raising awareness and fundraising efforts targeting key donors.
  - Additionally, it develops guidelines and standards for establishing baselines and verifying successful FLR efforts, contributing to improved reporting to the **Rio Conventions**.

12. International Whaling Commission (IWC)

The International Whaling Commission (IWC), established under the **International Convention for the Regulation of Whaling (ICRW)** signed in **Washington** DC in **1946**, has the objective of conserving whale stocks and regulating the whaling industry's development. Its headquarters are located in Impington, near Cambridge, England.

- In 1982, the IWC implemented a **moratorium on commercial whaling**, yet it permits non-zero whaling quotas for aboriginal subsistence purposes, and member nations may issue 'Scientific Permits' to their citizens for research purposes.

- However, the IWC's authority is limited as it operates as a voluntary international organization **without the backing of a treaty.**
- Notably, Japan withdrew from the IWC in December 2018.

NON-GOVERNMENTAL ORGANIZATIONS (NGOS)

1. Greenpeace

Founded in **1971 in Vancouver**, Canada, Greenpeace emerged from a collaboration among activists, journalists, and scientists united in their mission to protest and increase awareness about nuclear testing in the Pacific.

- **Campaigns and Activities:** Renowned for its direct action campaigns, Greenpeace employs strategies such as non-violent protests, civil disobedience, and imaginative stunts to highlight environmental concerns, covering a range of issues including climate change, deforestation, overfishing, pollution and nuclear proliferation.
- **Global Presence:** Greenpeace operates in over **55 countries** across the globe, with regional offices coordinating campaigns and activities tailored to local environmental challenges.
- **Independence:** Greenpeace is independent of any government, political ideology, or corporate interest. It relies on individual donations and support from members to fund its activities, which it considers crucial to maintaining its autonomy and integrity.
- **Impact:** Over the years, Greenpeace has been instrumental in raising awareness about environmental issues and influencing policies and practices. It has contributed to significant victories, such as the ban on nuclear testing, the establishment of protected marine reserves, and the phase-out of hazardous chemicals.
- **Recent events:** According to an analysis conducted by **Greenpeace Southeast Asia,** a non-governmental organization, the economic impact of air pollution, particularly **PM 2.5 pollution,** resulted in approximately **54,000 deaths** in Delhi in 2020.
  - In July 2020, Greenpeace found out that of the 28 global cities studied, Delhi bore the highest economic cost of air pollution, as a percentage of GDP due to the impacts of PM2.5 and NO_2 pollution.
  - Despite a strict Covid-19 lockdown, Delhi experienced an estimated loss of 24,000 lives in the first half of 2020 alone.
  - A Greenpeace estimate puts the economic cost for Delhi alone at 13 per cent of the state domestic product, amounting to nearly USD 8 billion in 2020.

2. World Wildlife Fund (WWF)

The **World Wide Fund for Nature** (WWF), commonly known as the World Wildlife Fund, is an international non-governmental organization founded in **1961.** The Headquarters of WWF is situated in Gland, Switzerland

Here are some key points about WWF:

- **Mission:** WWF's mission is to conserve nature and reduce the most pressing threats to the diversity of life on Earth. It aims to build a future where people live in harmony with nature by protecting species and their habitats, promoting sustainable use of natural resources, and advocating for environmental policies.
- **Global Presence:** WWF operates in over 100 countries, with offices and projects spanning diverse ecosystems, including forests, oceans, freshwater habitats and grasslands.
- **Priority Species and Habitats:** WWF focuses its conservation efforts on priority species and habitats that are particularly **vulnerable or critical for biodiversity** conservation. This includes iconic species such as tigers, elephants, pandas, whales, and marine turtles, as well as vital ecosystems like coral reefs, tropical rainforests, and river basins.
- **Policy Advocacy:** WWF engages in policy advocacy at the local, national, and international levels to influence environmental legislation, regulations, and agreements.
  - It participates in forums such as the United Nations Convention on Biological Diversity (CBD) and the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC).
- **Living Planet Report and Living Planet Index** are published by the World Wildlife Fund for Nature (WWF).
- **Earth Hour,** an annual initiative by the World Wildlife Fund for Nature (WWF), was initiated in 2007. It encourages participation from over 180 countries, urging individuals to turn off their lights from **8:30 pm to 9:30 pm** local time.
  - This symbolic gesture aims to conserve energy by avoiding unnecessary lighting, symbolizing a commitment to environmental protection.
  - Earth Hour takes place on the **last Saturday of March** each year.
- WWF is involved in the **TX2 Goal**, a global initiative aiming to double the world's wild tiger population by 2022.

3. TRAFFIC

TRAFFIC, the **Wildlife Trade Monitoring Network**, is a prominent non-governmental organization dedicated to addressing wildlife trade in the context of biodiversity conservation and sustainable development.

- It operates as a **joint program** of the World Wildlife Fund (**WWF**) and the International Union for Conservation of Nature (**IUCN**), with the goal of ensuring that the trade in wild plants and animals does not pose a threat to nature conservation.

- Established in 1976, TRAFFIC has evolved into a global network known for its research-driven and action-oriented approach, committed to delivering innovative and practical conservation solutions.
- **Headquartered** in **Cambridge**, United Kingdom, it **collaborates** closely with the Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (**CITES**).
- Comprising experts from various fields such as biology, conservation, academia, research, communication, and investigation, TRAFFIC works tirelessly to combat illegal wildlife trade, a significant factor contributing to the endangerment of many species.
- One of its notable initiatives, the "**Don't Buy Trouble**" campaign in **India**, aims to raise consumer awareness, particularly among tourists, about the risks associated with purchasing wildlife souvenirs during their travels.
  - This campaign has been successfully implemented since 2008 across various locations including airports, tiger reserves, national parks, wildlife resorts, schools, and colleges.
- Furthermore, TRAFFIC's ongoing campaign, the "**WANTED ALIVE**" series, focuses on four threatened **Asian big cats: the tiger, leopard, snow leopard, and clouded leopard.** These campaigns aim to address the illegal trade in body parts of these majestic animals.

4. Friends of the Earth International (FoEI)

Friends of the Earth International is among the largest **grassroots environmental federations** globally, comprising 70 national member groups and boasting millions of members and supporters worldwide. It was founded in 1971.

- Its **vision** entails the establishment of a society where **interconnected individuals** live with dignity, completeness and satisfaction, characterized by the realization of equity, human rights, and peoples' rights.
- This envisioned society is rooted in principles of **peoples' sovereignty** and active participation, founded on ideals of **social, economic, gender and environmental justice**.
- It aspires to be free from all forms of oppression and exploitation, including neoliberalism, corporate globalization, neo-colonialism, and militarism.

5. Environmental Defense Fund (EDF)

- US-based Environmental Defence Fund (EDF) launched the **Indian Zero Carbon Energy Pathways (IDEEA),** an **open-source energy model** tailored for India to aid in achieving carbon-neutral objectives.
  - IDEEA also serves as a platform for open-source energy modeling, addressing the need for comprehensive mathematical models.
  - Developed collaboratively by the Indian Institute of Science (**IISc**) in Bengaluru, the **Global Change Program** at Jadavpur University (GCP-JU) in Kolkata, and EDF, IDEEA offers **consumers options to minimize carbon-intensive energy consumption**.
  - This is based on the understanding that achieving carbon-neutral targets in India requires collaboration between government and industry stakeholders for a sustainable future.

6. Bird Life International

Established in London in 1922, BirdLife International is a global coalition of non-governmental organizations dedicated to bird and habitat conservation.

- With a membership exceeding **2.5 million individuals** and partner organizations spanning over 100 countries, BirdLife International focuses on various priorities, including:
  - Preventing bird species extinction,
  - Protecting vital bird habitats, and
  - Empowering conservationists worldwide.
- Guided by a global council, member organizations execute the group's strategies at local, regional and national levels.
- BirdLife International has identified **7,500 Important Bird Areas (IBAs)** and oversees the **management** of more than **2.5 million acres (1,000,000 hectares) of wildlife habitat**.
- Serving as the **official listing authority** for birds on the International Union for Conservation of nature(**IUCN**) **red list** of threatened species, BirdLife International has identified over **1,000 bird species facing extinction** and has devised **conservation plans** for each of them.

7. Center for Biological Diversity

The Center for Biological Diversity, a non-profit conservation organization based in Tucson, Arizona, focuses on conserving **wildlife and wildlands** through advocacy utilizing science, law, creative media, and organizing.

- Over the years, their **efforts** have resulted in **protections for over 700 species** of wildlife and plants, along with the **designation of 713 million acres of critical habitat** under the United States **Endangered Species Act.**
- They are currently working to get congress to pass the **Extinction Prevention Act.**
- Additionally, they have advocated for stringent climate regulations, cessation of fossil fuel extraction on U.S. public lands, stricter pesticide regulation, and wildlife trade controls.

8. Conservation International

Since its establishment in 1987, Conservation International (CI), an American Non-profit environmental organization, has been dedicated to highlighting and safeguarding the essential benefits that nature provides to humanity.

- Utilizing a comprehensive approach that integrates fieldwork, scientific innovations, policy development, and financial strategies, CI has successfully **protected** over **6 million square kilometers** (2.3 million square miles) of land and sea across more than 70 countries.

- CI's **primary objective** is to conserve nature as a fundamental source of food, fresh water, livelihoods, and climate stability.
- Its operational model involves:
  - Identifying and addressing the most pressing threats to nature.
  - Advocating for responsible industry practices that prioritize environmental preservation.
  - Sharing the knowledge and expertise accumulated over its first twenty-five years with governments and other stakeholders.
  - Through these efforts, CI strives to ensure a sustainable future where both human well-being and ecological integrity are upheld.

9. Climate Action Network (CAN)

Established in the 1980s, the Climate Action Network (CAN) has evolved into the **world's largest climate network**, comprising more than **1,900 civil society organizations** across over 130 countries, united in combating the climate crisis.

- Driven by its diverse membership and extensive experience in guiding the climate movement, CAN operates as a robust, member-oriented network spanning all six continents.
- It continually strives to foster collaboration and forge connections with partners and stakeholders throughout the climate movement and beyond, urging governments to take decisive and immediate action to combat the climate crisis, transition away from fossil fuels, and address the needs of the most vulnerable communities impacted by climate change.
- **The Climate Change Performance Index (CCPI):** It is jointly published annually by the **Climate Action Network, Germanwatch, and the New Climate Institute since 2005.**
  - CCPI is an independent tool used to monitor the climate protection efforts of **63 countries** and the European Union, representing over **92% of global Greenhouse Gas** (GHG) emissions.
  - In the CCPI 2024 ranking, **India** secured the **7th position**, making it the **only G-20 country in the top 10.**
  - Using standardised criteria, the CCPI looks at four categories, with 14 indicators: Greenhouse Gas Emissions (40% of the overall score), Renewable Energy (20%), Energy Use (20%), and Climate Policy (20%).
  - India has garnered high ratings in the categories of GHG emissions and energy use, along with medium scores in climate policy and renewable energy.
  - Additionally, the nation is making progress towards meeting its 2030 emissions targets, in line with a scenario aiming for temperature increases well below 2°C.

CONCLUSION

Overall, addressing climate change requires a coordinated and inclusive approach that integrates technological innovation, policy interventions, financial mechanisms, and international cooperation. Only through collective action can we mitigate the worst effects of climate change and build a more sustainable future for all.

"We are the first generation to be able to end Poverty and the last generation that can take steps to avoid the worst impacts of Climate Change. Future generations will judge us harshly if we fail to fulfill our historic and moral responsibilities" — Banki Moon, UN Ex-Secretary General.

Sustainable Development and Agriculture

13

SUSTAINABLE DEVELOPMENT

Sustainable development is like a symphony, weaving together the melodies of economic progress, social equity, and environmental guardianship. It's about crafting a future where prosperity harmonizes with compassion, and where nature's bounty is cherished as much as human ingenuity. Picture it as a dance of balance, where each step forward ensures that future generations inherit a world as rich in opportunities as it is in resources.

Take, for instance, the art of using recycled materials or tapping into renewable resources in our production processes. It's not just about making products; it's about orchestrating a future where innovation and conservation dance hand in hand, creating a rhythm of resilience that echoes through time.

The Concept of Development

Development is described as a **gradual progression wherein human capabilities expand,** enabling the initiation of novel frameworks, the management of challenges, adjustment to ongoing alterations, and purposeful and creative endeavors toward achieving fresh objectives.

It is a multifaceted phenomenon encompassing significant transformations in societal frameworks, mindsets, and establishments, alongside economic advancement, mitigation of disparity, and elimination of extreme poverty.

Differences between Economic Growth and Development

Economic growth refers to an increase in the quantity of goods and services produced in an economy, often measured by GDP. Economic development focuses on the quality of life improvement, including factors like education, healthcare, and environmental sustainability. It's about making the bigger pie more enjoyable and equitable for all.

Sustainable Development (SD)

Sustainable development advocates for collaborative endeavors aimed at constructing an inclusive, sustainable, and resilient future for both humanity and the environment.

Core Elements of Sustainable Development

The essential components of sustainable development encompass economic advancement, societal integration, and safeguarding the environment, necessitating their alignment.

Environmental Sustainability

- It aims to deter the exploitation of nature as an infinite resource while promoting its preservation and responsible utilization. Environmental sustainability is advanced through various measures including conservation efforts, investment in renewable energy, water conservation, promotion of sustainable transportation, and innovative approaches to construction and architecture.

Social Sustainability

- It has the potential to promote gender parity and the advancement of individuals, communities, and cultures, thereby contributing to a just and equitably distributed standard of living, healthcare, and education worldwide.

Economic Sustainability

- Emphasis is placed on achieving balanced economic advancement that fosters prosperity for everyone while preserving the environment. This involves investing in and fairly allocating economic resources, with the aim of eliminating poverty in its various manifestations.

IGNITE YOUR MIND

Decoding the Sustainability Enigma: Is sustainable development merely a buzzword or a decipherable code leading to a flourishing future? Crack the code by uncovering the core principles that guide this crucial concept and unlocking its potential impact.

Need for Sustainable Development

The need for sustainable development is critical for guaranteeing the well-being of both present and future generations. Some key reasons are:

Environmental Challenges

- **Resource Depletion:** Our current pace of resource consumption, like fossil fuels, water, and forests, is unsustainable. Sustainable development promotes responsible resource management, ensuring their availability for future generations.
- **Environmental Degradation:** Unsustainable practices lead to pollution, deforestation, and climate change. Sustainable development encourages practices that protect the environment and maintain ecological balance.

Social and Economic Needs

- **Poverty and Inequality:** Unequal access to resources and opportunities creates social and economic disparities. Sustainable development strives for equitable development and poverty reduction, ensuring all individuals have access to a good standard of living.
- **Health and Wellbeing:** Environmental degradation and poverty negatively impact human health. Sustainable development aims to foster healthy communities with access to clean air, water, and sanitation.

Interconnectedness

- The three pillars of sustainable development - economic, social, and environmental - are interconnected. Addressing one area positively impacts the others. For example, investing in renewable energy (environment) creates jobs (economy) and improves air quality (health).

Future Implications

- **Human Needs are Met:** Everyone has access to basic necessities like food, water, and shelter.
- **The Environment is Protected:** Natural resources are used responsibly, and ecosystems are preserved.
- **Economic Growth is Sustainable:** Economic prosperity is achieved without compromising the environment or creating social inequalities.

In conclusion, the need for sustainable development is undeniable. It is a collective responsibility to ensure a healthy planet, equitable societies, and a prosperous future for all.

Sustainable Development Concept Emergence

- **Malthusian Perspective on Population Growth and Resource Depletion**
  - As early as 1789, Malthus proposed the idea that the human population tends to increase at a geometric rate, whereas the availability of resources for subsistence grows at an arithmetic rate.
  - Consequently, population growth is prone to surpassing the capacity of natural resources to sustain the expanding populace. Without intervention to control the rapid growth rate of population, depletion or exhaustion of natural resources would inevitably lead to human suffering.
- **Emergence of Sustainable Development in Global Discourse**
  - The idea of sustainable development gained significant global acknowledgment for the first time in 1972 during the UN Conference on the Human Environment in Stockholm.
  - While the term itself wasn't explicitly mentioned, the international community endorsed the concept—now fundamental to sustainable development—that both development and environmental concerns, previously treated as distinct matters, could be harmoniously managed for mutual benefit.
- **The Brundtland Report:**
  - The World Commission on Environment and Development, led by Gro Harlem Brundtland from Norway, brought renewed attention to Sustainable Development (SD). This effort culminated in the production of the Brundtland Report titled "Our Common Future" in 1987.
  - The report articulated Sustainable Development as the type of development that fulfills the requirements of the current generation without compromising the ability of future generations to meet their own needs.
  - **Key Issues Highlighted:**
    - **Concept of Needs:** The report emphasized the significance of addressing the fundamental needs of the world's impoverished population, giving them paramount importance.
    - **Limitations Imposed by Technology and Social Organization:** It also stressed the limitations posed by the current state of technology and social structures on the environment's capacity to fulfill both present and future needs.

Major Events Related to Sustainable Development

Given table outlines the key events and milestones in the history of sustainable development within the United Nations framework.

Year	Event	Key Highlights
1972	United Nations Conference on the Human Environment (Stockholm Conference).	First major UN conference on the environment. Adopted the Stockholm Declaration and Plan of Action.
1992	Earth Summit in Rio de Janeiro (UN Conference on Environment and Development).	Adoption of Agenda 21, a global consensus on development and environmental cooperation. Produced the Rio Declaration and Statement of Forest Principles.
1997	Special Session of the General Assembly ('Earth Summit + 5').	Examined the implementation of Agenda 21. Proposed further implementation programs.
2000	Millennium Summit	Established the Millennium Development Goals (MDGs).

2002	World Summit on Sustainable Development (Johannesburg Summit).	Produced a new Action Plan.
2012	United Nations Conference on Sustainable Development (Rio+20).	Established the United Nations Environment Assembly. Became the high-level decision-making body on the environment.
2015	United Nations Summit on Sustainable Development.	Adoption of Agenda 2030 and its seventeen Sustainable Development Goals (SDGs).

Millennium Development Goals

During the Millennium Summit in September 2000, the most extensive assembly of global leaders to date endorsed the UN Millennium Declaration. This declaration pledged their countries to forge a fresh worldwide alliance aimed at diminishing severe poverty.

It also outlined a set of specific and time-sensitive objectives, commonly referred to as the Millennium Development Goals, with a deadline of 2015.

The Official English Names of the 8 Millennium Development Goals are

- Eradicate extreme poverty and hunger.
- Achieve universal primary education.
- Promote gender equality and empower women
- Improve maternal health.
- Reduce child mortality.
- Ensure environmental sustainability.
- Combat HIV/AIDS, malaria, and other diseases
- Develop a global partnership for development.

Develop a global partnership for development
Eradicate extreme poverty and hunger
Achieve universal primary education
Ensure environmental sustainability
2015
MILLENIUM DEVELOPMENT GOALS
Promote gender equality and empower women
Combat HIV/Aids, malaria and other diseases
Improve maternal health
Reduce child mortality

Fig. 13.1: The 8 Millennium Development Goals

The Sustainable Development Goals (SDGs), introduced in 2015, build upon the MDGs' achievements while addressing their limitations by encompassing broader themes such as environmental sustainability, social inclusion, and economic prosperity. The SDGs aim to create a more equitable and sustainable world by 2030, emphasizing the interconnectedness of global challenges and the need for collaborative action on a global scale.

IGNITE YOUR MIND

Time Traveling for Sustainability: Hop on a time machine and journey from the Earth Summit in Rio to the present day, witnessing the evolution of the sustainability movement. Analyze the key milestones achieved while grappling with the persistent challenges that continue to hold us back.

Sustainable Development Goals

The Sustainable Development Goals (SDGs) serve as comprehensive frameworks aimed at fostering a more sustainable and equitable future for all individuals. Essentially, the SDGs represent a set of seventeen specific targets endorsed by all UN member states in 2015 to enhance the prospects of future generations and are targeted to be achieved by 2030.

The SDGs, constituting an intergovernmental agreement, succeeded the Millennium Development Goals as the overarching development agenda beyond 2015. The Rio+20 summit held in Rio de Janeiro in 2012 was instrumental in shaping the SDGs, albeit as non-binding instruments.

The 17 Sustainable Development Goals are as Follows

1. **No Poverty:** End poverty in all its forms everywhere.
2. **Zero Hunger:** End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
3. **Good Health & well-being:** Ensure healthy lives and promote well-being for all at all stages.
4. **Quality Education:** Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
5. **Gender Equality:** Achieve gender equality and empower all women and girls.
6. **Clean Water and Sanitation:** Ensure availability and sustainable management of water and sanitation for all.
7. **Affordable and Clean Energy:** Ensure access to affordable, reliable, sustainable, and modern energy for all.
8. **Decent Work and Economic Growth:** Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.

9. **Industry, Innovation, and Infrastructure:** Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
10. **Reduced Inequality:** Reduce inequalities within and among countries.
11. **Sustainable Cities and Communities:** Make cities and human settlements inclusive, safe, resilient, and sustainable.
12. **Responsible Consumption and Production:** Ensure sustainable consumption and production patterns.
13. **Climate Action:** Take urgent actions to combat climate change and its impact.
14. **Life Below Water:** Conserve and sustainably use the oceans, seas, and marine resources.
15. **Life on Land:** Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably managed forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
16. **Peace, Justice, and Strong Institutions:** Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
17. **Partnership for the Goals:** Strengthen the means of implementation and revitalise the global partnership for sustainable development.

Differences between MDGs and SDGs

The SDGs draw upon the valuable insights gained from the MDGs. They also continue the uncompleted tasks of the MDGs to maintain progress and uphold the momentum achieved, while simultaneously tackling new challenges related to inclusivity, equity, and urbanization. Moreover, they enhance global partnerships by engaging civil society organizations (CSOs) and the private sector. The SDGs represent a seamless continuation and enhancement of the MDGs, ensuring their sustainability by reinforcing environmental objectives.

Aspect	SDGs	MDGs
Goals, Targets, and Indicators	Comprise 17 goals with 169 targets.	Consist of 8 goals, 21 targets, and 63 indicators.
Global Applicability	All countries, irrespective of their development status, are expected to work towards achieving SDGs.	Focus primarily on developing countries with funding predominantly from affluent nations.
Focus Areas	Rooted in the pillars of human development, human rights, and equity, with explicit references to people with disabilities, vulnerable individuals, and non-discrimination.	Lacked specific mentions of people with disabilities, vulnerable individuals, or non-discrimination.
Health Goals	Includes one comprehensive goal emphasizing well-being and healthy living, encompassing Non-communicable diseases.	Featured three direct health goals, four targets, and 15 indicators, focusing primarily on child and maternal mortality, and communicable diseases.
Timeframe and Baseline	Baseline set from 2015 estimates, with potential revisions based on newer data.	Utilized a 25-year timeframe from adoption in 2002, with baseline data from 1990, subject to subsequent revisions.
Role of Civil Society Organizations (CSOs)	Recognizes the role of Civil Society Organizations (CSOs) in holding governments accountable at the local level.	Did not assign a defined role for Civil Society Organizations (CSOs).
Implementation Mechanisms	Implementation mechanisms, including Means of Implementation (MoI) and monitoring systems, are being developed through governmental negotiations and global architecture.	Lack pre-defined Means of Implementation (MoI), monitoring, and follow-up mechanisms.

IGNITE YOUR MIND

MDGs vs. SDGs: Face-Off for the Future: Witness an epic clash of the titans! Compare and contrast the Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs), analyzing their successes, identifying new challenges, and determining which set of goals will ultimately lead us towards a better future.

India and SDGs

Status of India

According to the United Nations SDG Index and Dashboards Report 2023, which assesses countries' progress towards the Sustainable Development Goals (SDGs), the SDG Index Rank of India is 112 out of 166 countries, with an overall index score of 63.5 percent and spill-over score of 99.4 percent.

India has made significant progress towards achieving several Sustainable Development Goals (SDGs).

Assessment of India SDGs Progress

Goal	Progress	Challenges
Goal 1: No Poverty	India's multidimensional poverty has decreased significantly from 24.85% in 2015-16 to 14.96% in 2022-23. The rural areas have seen the fastest decline in poverty, from 32.59% to 19.28%.	The richest 1% of India's population owned over 40.5% of the country's wealth in 2021, according to a new report by Oxfam.
Goal 2: Zero Hunger	As per the recent report of NFHS-5 (2019-21), the nutrition indicators for children under 5 years have improved as compared with NFHS-4 (2015-16). Stunting has reduced from 38.4% to 35.5%, Wasting has reduced from 21.0% to 19.3% and Underweight prevalence has reduced from 35.8% to 32.1%.	Addressing malnutrition remains a challenge, particularly in vulnerable populations.
Goal 3: Good Health and Well-being	Healthcare indicators like life expectancy have improved, but access to quality healthcare remains unequal (source: NFHS-5).	Rural areas face disparities in healthcare access, with high maternal and child mortality rates.
Goal 4: Quality Education	Gross enrollment ratio in primary and secondary education has increased.	Education quality and dropout rates are concerns, alongside gender disparities. As of 2023, the Gross Enrolment Ratio (GER) for higher education in India is 27.1%.
Goal 5: Gender Equality	Legal strides have been made, but gender gaps persist in education, employment, and political participation (Gender Gap Report - World Economic Forum).	Ensuring gender equality across all sectors remains a challenge.
Goal 6: Clean Water and Sanitation	Swachh Bharat Abhiyan has improved rural sanitation, yet access to safe drinking water remains a challenge.	Water pollution and inadequate access to safe drinking water persist.
Goal 7: Affordable and Clean Energy	Efforts to expand electricity access and renewable energy have been made.	Ensuring energy affordability for all and reducing coal dependence are challenges.
Goal 8: Decent Work and Economic Growth	Economic growth has created jobs, yet informal employment remains widespread.	Ensuring decent working conditions and social protection for all workers is crucial.
Goal 9: Industry, Innovation, and Infrastructure	Rapid growth in the digital sector and infrastructure development has been observed.	Bridging the digital divide and ensuring equitable access to infrastructure are essential.
Goal 10: Reduced Inequalities	Financial inclusion efforts have been made, yet significant income and social inequalities persist.	Addressing inequalities based on gender, caste, and religion remains a challenge.
Goal 11: Sustainable Cities and Communities	Urban infrastructure improvement initiatives have been undertaken.	Rapid urbanization poses challenges like inadequate housing and pollution.
Goal 12: Responsible Consumption and Production	Initiatives for sustainable practices have been implemented, yet reducing resource consumption remains a challenge.	Promoting circular economy principles and minimizing waste generation are significant hurdles.

Goal	Progress	Challenges
Goal 13: Climate Action	Ambitious climate targets have been set, with initiatives like the National Solar Mission.	Reducing greenhouse gas emissions and adapting to climate change impacts remain major challenges.
Goal 14: Life Below Water	Efforts to conserve marine biodiversity and promote sustainable fisheries practices have been undertaken.	Addressing overfishing and marine pollution requires more robust measures.
Goal 15: Life on Land	Initiatives like the National Mission for Sustainable Agriculture aims to protect forests and biodiversity (source: Ministry of Environment, Forest and Climate Change).	Deforestation and biodiversity loss remain significant concerns, requiring innovative approaches.
Goal 16: Peace, Justice and Strong Institutions	Improvements in indicators like crime rates have been seen, yet corruption and social conflict persist.	Strengthening institutions and ensuring equal access to justice are ongoing challenges.
Goal 17: Partnerships for the Goals	India actively engages in international partnerships on SDG-related issues.	Ensuring effective coordination and resource mobilization for achieving the SDGs requires stronger partnerships.

SDG India Index 2020-21

Overview:

- Published by **NITI Aayog**, the SDG India Index tracks progress on 17 goals, 70 targets, and 115 indicators.
- Collaboratively developed with the United Nations, it assesses both national and subnational progress towards global goals.

State Classification and Performance:

- States are categorized as aspirants, performers, front runners, or achievers based on their scores.
- Kerala leads with a score of 75, while Bihar, Jharkhand, and Assam lag behind.

India's Progress:

- India's overall SDG score improved from 60 in 2019 to 66 in 2020-21, driven by notable achievements in clean water, sanitation, and clean energy.
- Concerns persist in areas like zero hunger and gender equality, where scores remain low.

Areas of Concern and Improvement:

- Goal 2 (Zero Hunger) and Goal 5 (Gender Equality) require concerted efforts, with many states falling behind.
- While some states excel, others require significant attention and policy reforms.

The Path Forward:

- Addressing critical areas through evidence-based policy-making and cross-learning between states is essential.
- Goal 3 (Good Health and Well-being) shows improvement but requires sustained efforts.

In conclusion, despite challenges posed by the COVID-19 pandemic, India demonstrates progress towards SDG 2030 goals through cooperative federalism and targeted interventions, signaling a positive trajectory.

Sustainable Development Goals Progress Report 2023

Recently, the UN Department of Economic and Social Affairs (UNDESA) released the Sustainable Development Goals (SDG) Progress Report 2023. This report monitors global progress on the 17 SDGs outlined by the United Nations.

Here are some key Highlights from the Report

- **Progress Assessment:** The report indicates that progress on over 50% of the SDG targets is inadequate, with nearly 30% showing no improvement or regression.
- **Impact of Global Challenges:** The COVID-19 pandemic, coupled with issues such as climate change, biodiversity loss, and escalating pollution, is exacerbating existing challenges and hindering progress towards sustainable development goals.
- **Education Concerns:** By 2030, the report predicts that approximately 84 million children will be out of school, and nearly 300 million enrolled children will lack basic literacy skills.
- **Persistent Poverty:** If current trends persist, an alarming 575 million people are projected to live in extreme poverty by 2030, underscoring the urgency of addressing socioeconomic disparities.

In light of these findings, the report offers several recommendations:

- **Renewed Commitment:** Heads of state and governments are urged to reaffirm their commitment to advancing the SDGs and prioritize collective action to address pressing global challenges.
- **Fulfilling Commitments:** The international community is called upon to honor the commitments outlined in the Addis Ababa Action Agenda, which provides a comprehensive framework for financing sustainable development initiatives.

- **Targeted Interventions:** More targeted policies and actions are essential to eradicate poverty, reduce inequality, and promote the rights of women and girls, emphasizing the importance of inclusive and gender-responsive approaches.
- **Strengthening Multilateralism:** To effectively address current challenges, there is a critical need to enhance the capacity of the multilateral system, fostering collaboration and coordination among nations and stakeholders.

Overall, the report underscores the urgency of collective action and underscores the need for sustained commitment and concerted efforts to achieve the SDGs by 2030.

IGNITE YOUR MIND

India's SDG Quest: Embark on a thrilling quest to discover how India is translating the SDGs into action. Explore the unique strategies and initiatives undertaken, but don't shy away from dissecting the hurdles and unforeseen obstacles encountered along the way.

Impact of SDGs

The Sustainable Development Goals (SDGs), adopted by the UN in 2015, aspire to forge a more just, equitable, and sustainable world by 2030. Though ongoing, the SDGs have already exerted a profound influence on diverse facets of existence.

- **Enhanced Global Awareness:**
  - The SDGs have significantly raised awareness worldwide about pressing global challenges, such as poverty, hunger, climate change, and inequality.
  - **Example:** Initiatives like the Global Goals Week and World's Largest Lesson have engaged millions of people, schools, and organizations globally, promoting understanding and action towards achieving the SDGs.
- **Mobilization of Resources and Investments:**
  - The SDGs have attracted substantial public and private investments towards sustainable development initiatives.
  - **Example:** Green Climate Fund has mobilized billions of dollars to support climate-related projects in developing countries, fostering clean energy adoption and resilience-building efforts.
- **Policy and Regulatory Reforms:**
  - Many countries have integrated the SDGs into their national policies and development plans, driving legislative and regulatory changes.
  - **Example:** In India, the National Action Plan on Climate Change aligns with SDG 13 (Climate Action), guiding policy decisions and initiatives to mitigate climate change impacts and promote sustainable development.
- **Promotion of Innovation and Technology:**
  - The SDGs have spurred innovation and technological advancements aimed at addressing various global challenges.
  - **Examples** include the development of affordable solar technologies in sub-Saharan Africa, empowering communities with access to clean energy and supporting SDG 7 (Affordable and Clean Energy).
- **Monitoring Progress and Addressing Gaps:**
  - The SDG framework provides a structured mechanism for monitoring progress and identifying areas requiring further attention.
  - **Example:** Platforms like the SDG Tracker by the Sustainable Development Solutions Network offer real-time data and analysis, enabling stakeholders to track progress and prioritize actions to achieve the goals.

Localization of SDGs

Localization of the SDGs refers to the process of **adapting the Sustainable Development Goals (SDGs) to the specific cont**ext of sub-national regions, such as states, provinces, or cities. The Ministry of Panchayati Raj has been actively pursuing the localisation of Sustainable Development Goals (SDGs) through Gram Panchayat Development Plan (GPDP), which involves participatory planning by converging various schemes to achieve specific SDGs. The objective of GPDP is to fulfill the Constitutional mandate of Gram Panchayats, aiming for economic development and social justice at the grassroots level.

Benefits of Localisation of SDGs

- **Tailored Solutions:** Localisation allows for the development of tailored solutions that address specific local needs and challenges.
- **Community Empowerment:** Involving local communities in the planning and implementation of SDGs enhances their sense of ownership and empowerment.
- **Efficient Resource Allocation:** Localisation ensures that resources are allocated efficiently, targeting areas and populations most in need.
- **Faster Implementation:** By decentralizing decision-making and action, localisation enables faster implementation of SDG initiatives.
- **Enhanced Accountability:** Local governments are more accountable to their constituents, leading to greater transparency and responsiveness in SDG implementation efforts.

Challenges in SDG Localisation

- Limited availability of finance, data, and capacities for subnational monitoring.
- Lack of policy coherence and coordination between national and local efforts.

- Enhanced responsibilities with limited funds transfer and local resource mobilization.
- Limited awareness of the SDGs at the sub-national level.
- Necessity for local translation and adaptation in a diverse country like India.

Efforts taken for the Localization of SDGs

- In India, the National Institution for Transforming India (NITI Aayog) oversees the adoption and monitoring of SDGs in the country while promoting competitive and cooperative federalism among States and Union Territories (UTs).
- The annual 'SDG India Index,' launched by NITI Aayog in 2018, monitors progress at the state and UT levels.

Examples of Successful Localisation from States

- **Andhra Pradesh: Implemented 'Navaratnalu,'** a cluster of nine flagship programs targeting vulnerable communities across sectors such as agriculture, health, education, and housing.
- **Bihar: Implemented 'Viksit Bihar ke 7 Nischay,'** a package of programs focusing on inclusion, entrepreneurship, women's reservation in jobs, provision of essential amenities, and higher education.

Way Forward

- Emphasize people-centric, gender-responsive, and community-responsive localisation of SDGs.
- Establish robust monitoring and evaluation mechanisms through effective partnerships among all SDG stakeholders.
- Foster learning from shared experiences to overcome functional silos and address global challenges through local actions.
- Raise awareness about SDGs in Panchayati Raj Institutions (PRIs) and empower rural local bodies through proper devolution of Funds, Functions, and Functionaries.

Challenges in Realization of SDGs

At Global Level

- **Global Economic Growth is Sluggish:** In order to meet the Sustainable Development Goals (SDGs), the world must achieve an annual growth rate of 2.5 percentage points. However, up to 2021, global growth has only reached 0.36 percentage points, which is nearly seven times slower than that of the United States.
  - The COVID-19 pandemic halted progress worldwide from 2019 to 2021.
- **Utilizing Linear Extrapolation:** To demonstrate the disparity between expectations and actual progress, linear extrapolation can be employed to forecast a future date for achieving perfection globally. However, this is a simplification, as countries nearing completion on certain goals may shift focus and resources to other objectives.
- **Unrealistic Commitments:** Certain commitments, such as ending wars, poverty, climate change, hunger, and diseases, are impractical and difficult to achieve.
- **Lack of Focus:** With 169 targets, there is a lack of prioritization, making it challenging to concentrate efforts. Many countries are unable or unwilling to allocate sufficient funds to fulfill all their promises.

At Indian Level

- **Deteriorating Outlook:** As per the Lancet report, several districts are projected to fall short of Sustainable Development Goals (SDGs) even beyond 2030 due to a worsening trend observed between 2016 and 2021.
- **Financial Challenges:** Achieving SDG targets such as zero hunger and poverty necessitates substantial investments for their eradication. With one-third of the world's 1.2 billion extremely poor residing in India, the government alone lacks the resources to fund these ambitious SDG targets.
- **Monitoring and Implementation Ownership:** While NITI Aayog is anticipated to assume a pivotal role, concerns have been raised by its members regarding their limited manpower to effectively handle such an immense undertaking.

Limits to Growth Theory

Commissioned by the Club of Rome, "The Limits to Growth" (LTG) is a 1972 report addressing the challenges posed by exponential economic and population expansion against a backdrop of finite resource availability.

The conclusions reached by the research team were as follows:

- Without changes to historical growth patterns, **Earth would hit its limits by 2072,** resulting in an abrupt and uncontrollable decline in both population and industrial capacity. This includes:
  - Peak in global industrial output per capita around 2008, followed by rapid decline.
  - Peak in global food per capita around 2020, followed by rapid decline.
  - Peak in global services per capita around 2020, followed by rapid decline.
  - Peak in global population in 2030, followed by rapid decline.
- Growth patterns observed in 1972 could be modified to attain sustainable ecological and economic stability.

Initiatives taken to Achieve SDG Targets

Global Level

- **Paris Agreement on Climate Change:** Aligned with SDG 13 (Climate Action), this landmark agreement, adopted by 196 countries, aims to limit global warming and address climate change. It has spurred investments in renewable energy, carbon reduction strategies, and climate adaptation measures worldwide.
- **Sendai Framework for Disaster Risk Reduction:** Corresponding to SDG 11 (Sustainable Cities and Communities), this framework advocates proactive disaster preparedness, risk reduction, and early warning systems. It promotes international cooperation in sharing best practices and resources to enhance resilience against natural hazards.
- **Addis Ababa Action Agenda on Financing for Development:** Linked with SDG 17 (Partnerships for the Goals), this agenda recognizes the pivotal role of financing in achieving the SDGs. It encourages innovative financing mechanisms, increased public and private investments, and debt relief for developing countries.
- **Global Goals Platform:** Aligned with SDG 17 (Partnerships for the Goals), this online platform serves as a central hub for information, resources, and collaboration on SDG achievement. It facilitates knowledge sharing, partnerships, and engagement among governments, businesses, and civil society.
- **Global Fund for Women:** Supporting SDG 5 (Gender Equality) and SDG 3 (Good Health and Well-being), this organization empowers women and girls through grants and capacity-building programs. It focuses on critical areas for SDG attainment such as health, education, and economic empowerment.

National Level

- **National Level Pradhan Mantri Jan-Dhan Yojana (PMJDY):** Aligned with SDG 1 (No Poverty) and SDG 10 (Reduced Inequalities), PMJDY aims to provide financial inclusion by ensuring access to banking services, promoting economic empowerment, and reducing income disparities.
- **Ayushman Bharat - Pradhan Mantri Jan Arogya Yojana (AB-PMJAY):** Supporting SDG 3 (Good Health and Well-being), this scheme provides health insurance coverage to vulnerable populations, promoting universal health coverage and reducing health inequalities.
- **Skill India Mission:** Corresponding to SDG 8 (Decent Work and Economic Growth), this initiative aims to enhance employability and entrepreneurship skills, fostering inclusive and sustainable economic growth and promoting job creation.
- **Beti Bachao, Beti Padhao:** Aligned with SDG 5 (Gender Equality) and SDG 4 (Quality Education), this campaign aims to address gender-based discrimination, promote girl child education, and empower women, contributing to gender equality and inclusive education.
- **Pradhan Mantri Kisan Samman Nidhi (PM-KISAN):** Supporting SDG 2 (Zero Hunger), this scheme provides direct income support to small and marginal farmers, enhancing food security, reducing poverty, and promoting sustainable agriculture.
- **Ujjwala Yojana:** Aligned with SDG 7 (Affordable and Clean Energy), this initiative provides access to clean cooking fuel to households below the poverty line, reducing indoor air pollution and improving public health.
- **Start-Up India:** Corresponding to SDG 9 (Industry, Innovation, and Infrastructure), this initiative aims to promote entrepreneurship and innovation, fostering sustainable economic growth and job creation through the development of a robust startup ecosystem.
- **Pradhan Mantri Awas Yojana (PMAY):** Supporting SDG 11 (Sustainable Cities and Communities), PMAY aims to provide affordable housing to all urban households, addressing housing shortages, slum proliferation, and inadequate living conditions.

The absence of prioritization in allocating funds within national budgets has been a persistent issue during the implementation of the Millennium Development Goals (MDGs). A comparable lack of accountability is observed at the levels of ministries, states, and local administrations. If we are to genuinely commit to the Sustainable Development Goals (SDGs), accountability must be enhanced across all tiers of governance.

About SDG Financing

- The **Addis Ababa Action Agenda of 2015** establishes a worldwide framework for financing sustainable development, aiming to align all financial flows and policies with economic, social, and environmental priorities.
- India plays a pivotal role in determining the global success of the Sustainable Development Goals (SDGs), requiring an investment of $2.64 trillion to meet them. To achieve this, India must increase its SDG spending by an additional 6.2% of its GDP until 2030.
- **Initiatives for SDG financing include** the SDG Financing Lab, led by the OECD, which aims to provide guidance to decision-makers and policy leaders on securing the necessary resources for achieving the 2030 Agenda. Additionally, the SDG Fund, established in 2014 by the United Nations, serves as an international multi-donor and multi-agency development mechanism supporting sustainable development endeavors.

Green Economy

- A green economy is characterized by its **focus on minimizing carbon footprint, maximizing resource utilization, and fostering social equity**.
- Within this framework, both public and private investments stimulate job creation and income growth through initiatives, infrastructure, and assets aimed at curbing carbon emissions and pollution, improving energy and resource efficiency, and safeguarding biodiversity and ecosystem services.
- The concept of a green economy doesn't supplant sustainable development but rather **brings a fresh emphasis on economic aspects, investments, capital, infrastructure, employment, skills, and favorable social and environmental results** throughout the Asia-Pacific region.

Present Efforts on Green Economy Primarily Concentrate on Three Key Domains

- **Promotion of a macroeconomic strategy** for achieving sustainable economic growth through engagement in regional, subregional, and national platforms.
- **Illustration of Green Economy methodologies** with an emphasis on facilitating access to green finance, technology, and investments.
- **Assistance** provided to nations in the development and integration of macroeconomic policies aimed at facilitating the shift towards a Green Economy.

The significance of Green Economy, Sustainable Consumption and Production, and Resource Efficiency in advancing Sustainable **Development:**

- **Sustainable Consumption and Production targets leads to enhancement** of production methods and consumption habits to minimize resource utilization, waste production, and emissions throughout the entire lifecycle of processes and goods.
- **Resource Efficiency** pertains to optimizing resource utilization to provide societal value, striving to diminish resource consumption, emissions, and waste generation per unit of product or service.
- The **Green Economy** offers a macroeconomic strategy for sustainable economic expansion, emphasizing investments, employment, and skill development.

Partnership for Action on Green Economy (PAGE)

Established in 2013 in response to the call made at Rio+20, PAGE was created to assist countries seeking to transition towards more environmentally sustainable and inclusive growth models.

- **Objectives:** PAGE integrates sustainability into economic policies in line with the 2030 Agenda, aiming to aid nations in restructuring economies for growth, job creation, poverty reduction, and ecological resilience.
- **Collaborative Framework:** PAGE brings together five UN agencies - UN Environment, ILO, UNDP, UNIDO, and UNITAR - pooling expertise and resources to support inclusive green economy initiatives effectively.
- **Role in UN Coordination**: As a UN coordination mechanism, PAGE helps countries achieve and monitor SDG 8, promoting sustainable economic growth, employment, and decent work for all.

Way Forward

- **SDG Revolution:** The SDGs are reshaping development, demanding new strategies and partnerships.
- **Precision Monitoring - SDG India Index:** The recalculated index closely tracks State/UT progress annually, addressing gaps for a dynamic evaluation framework.
- **Whole-of-Society VNR:** India's VNR adopts a "whole-of-society" approach, engaging extensively to address Agenda 2030 issues.
- **Capacity Building for SDGs:** UN collaboration brings a comprehensive program for training in SDG monitoring, localization, and more.
- **Collaborative SDG Financing:** NITI Aayog partners with the IMF to estimate and refine SDG financing, with future state-specific exercises planned.
- **Focus on Backward States:** NITI Aayog collaborates closely with historically underdeveloped States, aiding in SDG adoption, monitoring, and institutional development.

IGNITE YOUR MIND

Earth's Tightrope Walk: You're a blindfolded acrobat balancing on a tightrope stretched over a chasm of population growth, resource depletion, and climate change. Can you reach the other side, representing a sustainable future, or will you fall victim to the forces pulling you down? How can we navigate this precarious path to ensure a thriving future for all?

In conclusion, the aim of sustainable development is to fulfill current needs without compromising the ability of future generations to meet their own needs. This necessitates a departure from current levels of resource consumption, as preserving resources is essential for the well-being of future generations. Consequently, the United Nations has

established 17 global sustainable development goals aimed at promoting peace, health, and prosperity by 2030. The concept of sustainable development was officially introduced in the Brundtland Report of 1987, marking a significant milestone in global sustainability efforts.

SUSTAINABLE AGRICULTURE

The world's food supply faces a precarious future. Traditional agricultural practices, while feeding billions, contribute to environmental degradation, resource depletion, and climate change. Sustainable agriculture emerges as the crucial answer. It envisions nourishing the planet and its people by harmonizing food production with environmental protection, ensuring a healthy future for generations to come.

MAJOR ISSUES IN INDIAN AGRICULTURE

The transformation of agriculture, while increasing food production, has resulted in detrimental issues such as erosion and deforestation. Food losses and waste contribute significantly to environmental challenges, accounting for 8% of greenhouse gas emissions. Climate change further exacerbates the situation by reducing the capacity of natural resources to support the growing demand for food, creating a direct link between food security and climate change challenges.

Vulnerability of Indian Agriculture

- **Overexploitation of Groundwater:** Rampant reliance on groundwater for irrigation purposes is depleting aquifers at an alarming rate, leading to acute water scarcity and land subsidence in various regions.

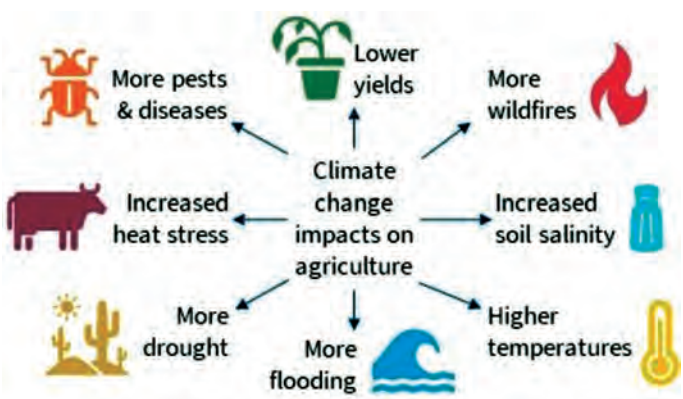


Fig. 13.2: Impact of Climate Change on Agriculture.

  - **Example:** Central Ground Water Board highlights that India's groundwater levels have declined by an average of 0.4 meters per year over the past two decades.
- **Monoculture Farming:** Excessive dependence on monoculture farming practices makes crops more vulnerable to pests and diseases, degrades soil fertility, and diminishes overall biodiversity.
  - **Example:** Studies conducted by the Indian Institute of Soil Science reveal a steady decline in soil organic carbon levels in regions dominated by monoculture cropping systems.
- **Excessive Use of Chemical Inputs:** Widespread usage of chemical fertilizers and pesticides in Indian agriculture is causing soil and water contamination, endangering beneficial insects, and posing health hazards to humans.
  - **Example:** India is among the world's top consumers of chemical pesticides, with over 60,000 tons used annually since 2017.
- **Burning of Crop Residues:** The prevalent practice of burning crop residues after harvest not only releases harmful pollutants into the atmosphere but also depletes valuable organic matter essential for soil fertility.
- **Limited Adoption of Sustainable Practices:** Despite the potential benefits, the widespread adoption of sustainable agricultural practices among smallholder farmers is hindered by knowledge gaps, financial constraints, and inadequate infrastructure.
- **Impact of Natural Disasters:** Agriculture sector severely impacted by changes in natural disaster frequency and magnitude, risking lives and livelihoods.
- **Factors Making Agriculture Vulnerable:**
  - Land degradation, water scarcity, and biodiversity loss exacerbate vulnerability to climate change.
  - Groundwater is crucial for irrigation and yield stability.
  - Less than 20% of net sown area is irrigated in 145 districts.
  - Paddy fields are a major methane gas emission source due to anaerobic decomposition.
  - Coastal districts, e.g., Odisha, prone to cyclones and floods.

Agricultural Emissions

Agricultural emissions refer to the release of greenhouse gases (GHGs) into the atmosphere as a result of various agricultural activities. These emissions primarily consist of methane (CH_4) and nitrous oxide (N_2O), which are potent GHGs contributing to global warming and climate change. Agricultural emissions occur from practices such as livestock farming, rice cultivation, the use of synthetic fertilizers, and the burning of agricultural residues.

Status of Agricultural Emission

- According to the United Nations' Food and Agriculture Organization (FAO), agriculture and related land use emissions constituted 17% of all Greenhouse Gas (GHG) emissions in 2018.
- Within the agriculture sector, 61.3% of GHG emissions are linked to the livestock sector, followed by 19.1% from fertilizer application, 17.5% from rice cultivation, and 2.2% from the field burning of agricultural residues.
- In India, major contributors to these emissions are states like Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal.

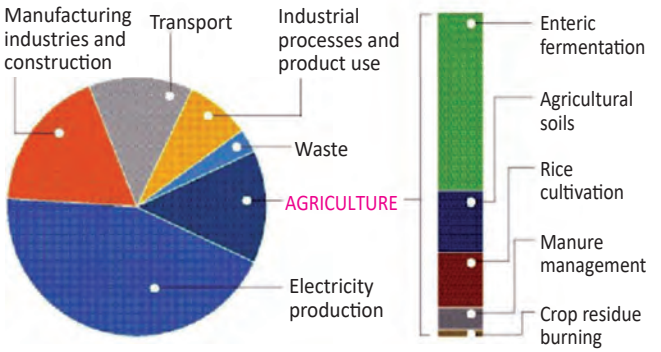


Fig. 13.3: The Share of Emissions

- **GHG Emissions in India:**
  - Indian agriculture emits 408 million metric tons (MMT) of CO_2 equivalent.
  - Rice cultivation accounts for approximately 17.5% of GHG emissions, trailing enteric fermentation (54.6%) and fertilizer use (19%).
- **Paddy Fields and GHG Emissions:** Paddy fields notably contribute to anthropogenic emissions of nitrous oxide (N_2O) and methane (CH_4), with high global warming potential compared to CO_2, as indicated by IPCC AR6 (2021).
- Agricultural soils contributed to over 70% of N_2O emissions from India in 2010, followed by waste water (12%) and residential and commercial activities (6%). Since 2002, N_2O has replaced methane as the second largest Greenhouse Gas (GHG) from Indian agriculture.
- Cattle account for majority of the ammonia production environment.
- Poultry industry releases reactive nitrogen compounds into the environment. The poultry industry recorded an excretion of reactive nitrogen compounds of 0.415 tonnes in 2016. That is anticipated to increase to 1.089 tonnes by 2030.

Sources of Agricultural Emission

- Microbes in the digestive tract produce methane during the fermentation of food.
- Methane is emitted from paddy fields due to anaerobic decomposition of organic matter in standing water.
- Anaerobic and aerobic decomposition of manure releases methane and nitrous oxide.
- Nitrous oxide emissions result from synthetic nitrogen additions to soils, particularly from urea.
- Decomposition of nitrogen in crop residues and burning of residues release nitrous oxide.
- Inefficient irrigation pumps contribute to energy consumption, releasing carbon dioxide, methane, and nitrous oxide from fuel burning and electricity generation.

Impact

- **Climate Impact:** Agriculture intensifies global warming by emitting potent greenhouse gases like methane and nitrous oxide, leading to higher temperatures, erratic weather patterns, and reduced crop yields.
- **Air Pollution:** Agricultural emissions of ammonia and nitrogen oxides contribute to harmful fine particulate matter and ozone formation, worsening respiratory health issues.
- **Water Contamination:** Nutrient-rich runoff from fertilizers and manure pollutes water bodies, harming aquatic ecosystems, compromising drinking water quality, and promoting harmful algal blooms.
- **Soil Degradation:** Unsustainable practices such as excessive tilling degrade soil fertility and productivity, exacerbating erosion and diminishing carbon storage capacity.
- **Biodiversity Decline:** Habitat destruction, pesticide use, and monoculture farming practices threaten biodiversity, impacting pollinator populations, disrupting ecosystems, and reducing resilience to climate change.

Internationally, numerous countries have established ambitious goals to achieve net zero emissions by 2050, with India setting a target of 2070. However, achieving net zero emissions is contingent upon decarbonizing the agriculture sector. While the primary responsibility lies with developed nations, the Indian government must also implement measures to decarbonize agriculture without jeopardizing food security, livelihoods, and farmers' incomes. This concerted effort will expedite India's transition towards achieving net zero emissions.

SUSTAINABLE AGRICULTURE

Sustainable Agriculture involves cultivating methods that optimize natural resource utilization, minimize environmental harm, and enhance resilience to climate change without compromising the needs of future generations. Recognizing the importance of ecological services forms the basis of sustainable agriculture, a concept that has gained momentum since the publication of the Brundtland Report in 1987.

Sustainable Agriculture Concept

- Sustainable agriculture balances current food production with the needs of future generations, avoiding soil degradation and environmental harm.
- It integrates environmental health, economic profitability, and social equity, prioritizing natural resource conservation and ecosystem preservation.
- Sustainable agriculture includes practices like crop rotation, minimal tillage, and organic manure use, minimizing reliance on artificial inputs like fertilizers and pesticides.
- It manages renewable resources holistically, maintaining productivity and ecosystem services for current and future generations.

Sustainable Agriculture Principles

- **Environmental Sustainability:** Sustainable environmental practices encompass the protection, recycling, substitution, and preservation of the natural resource foundation, comprising land (soil), water, and wildlife.
- **Economic Sustainability:** Economic sustainability is attained by improving crop rotation and soil conservation practices, leading to enhanced yields.
- **Social Sustainability:** Upholding social justice and cultural cohesion is vital for attaining social sustainability.
- **Reduction of Non-renewable and Unsustainable Inputs:** It's imperative to minimize the use of non-renewable and environmentally harmful inputs, thereby lessening the ecological footprint of agricultural activities.
- **Leveraging Farmer Expertise for Sustainability:** Farmers' expertise is invaluable not only in maximizing agricultural productivity but also in promoting self-reliance and self-sufficiency within farming communities. Their insights and knowledge play a crucial role in shaping sustainable farming practices.
- **Promotion of Biodiversity:** Encouraging biodiversity within agricultural systems enhances resilience to pests, diseases, and climate change while also providing ecosystem services such as pollination and natural pest control.
- **Water Conservation and Management:** Implementing practices that optimize water use efficiency, such as drip irrigation and rainwater harvesting, helps conserve water resources and reduce agricultural water consumption.

IGNITE YOUR MIND

Climate Crossroads for Agriculture: A Looming Choice: Agriculture stands at a critical juncture. Can we cultivate a future where food production prospers in harmony with the environment, or are we destined for a devastating collision course between the two? Unpack the complex relationship between agriculture and climate change, and explore potential solutions to navigate this looming crisis.

Sustainable Agricultural Practices

Sustainable agricultural practices prioritize methods that promote long-term ecological balance, economic viability, and social equity within farming systems. These practices aim to minimize environmental impact, conserve natural resources, and support resilient and productive food production systems that meet the needs of present and future generations.

Agricultural Practice	Description
Mulching	The practice of covering the soil surface with materials like straw, leaves, or plastic to conserve moisture, suppress weed growth, and improve soil health.
Zero Tillage	A farming technique where the soil is left undisturbed, minimizing soil erosion, preserving soil structure, and reducing labor and fuel costs associated with tillage.
Agro-Ecology	An approach to agriculture that emphasizes ecological principles and seeks to optimize interactions between plants, animals, humans, and the environment to create sustainable farming systems.
Organic Farming	A method of agriculture that relies on natural inputs and biological processes instead of synthetic chemicals to enhance soil fertility, control pests and diseases, and produce healthy crops.
Zero Budget Natural Farming	A farming approach that promotes chemical-free, low-cost farming methods by utilizing natural resources and minimizing external inputs such as fertilizers and pesticides.
Intensive Agricultural Practices	Farming methods that aim to maximize yields and efficiency through high input usage, advanced technology, and precise management techniques.
Permaculture	A design system that mimics natural ecosystems to create sustainable human habitats and food production systems by integrating plants, animals, landscapes, and structures in mutually beneficial ways.
Vertical Farming Systems	Agricultural systems that utilize vertical space to grow crops in stacked layers or vertical towers, often indoors or in controlled environments, to optimize land use and reduce resource consumption.
Integrated Pest Management (IPM)	A holistic approach to pest control that combines biological, cultural, physical, and chemical methods to manage pests while minimizing risks to human health and the environment.
System of Rice Intensification (SRI)	SRI techniques encompass methods such as early seedling transplantation, occasional watering, and fostering aerobic soil conditions. These approaches lead to increased crop yields and reduced water usage.
Conservation Agriculture	Conservation agriculture techniques like zero or minimal tillage, managing residue, and rotating crops are being adopted to diminish soil erosion, enhance soil vitality, and conserve water resources.

Mulching

Mulching is the practice of covering the soil surface with a layer of material, typically organic in nature. This layer acts as a protective barrier for the soil and benefits plant growth in various ways.

Types of Mulching

- **Organic Mulches:** These are preferred as they decompose over time, adding nutrients to the soil. Examples include wood chips, bark, shredded leaves, compost, and straw.
- **Inorganic Mulches:** These include plastic sheeting, landscape fabric, and stones. They offer different benefits but don't decompose and enrich the soil.

Significance of Mulching

- **Moisture Retention:** Mulch acts as a protective layer, shielding the soil from sunlight and wind.
  - This significantly reduces evaporation, helping retain soil moisture and keeping plants hydrated for longer, especially during dry periods. This can be particularly crucial in regions with limited rainfall or hot summers.
- **Weed Suppression:** Mulch creates a physical barrier that blocks sunlight, hindering weed seed germination and growth.
  - This reduces competition for water and nutrients from your desired plants, lessening the need for frequent weeding.
- **Improved Soil Quality:** As organic mulch decomposes over time, it releases nutrients back into the soil, enriching its fertility and promoting healthy plant growth.
  - Additionally, the decomposition process can improve soil structure and drainage.

Challenges of Mulching

- **Cost:** Mulch can be an additional expense, especially for large areas. The cost can vary depending on the material chosen and the quantity required.
- **Maintenance:** Mulch may require some maintenance, such as replenishing it as it decomposes or removing weeds that grow through it.

Way Forward

- **Education:** Raising awareness about the benefits of mulching can encourage more people to adopt this practice. Educational initiatives can be targeted towards homeowners, gardeners, and landscapers.
- **Availability:** Making various mulch materials readily available and accessible can help overcome the challenge of choosing the right material and acquiring it. This can involve promoting local suppliers of mulch and encouraging the use of recycled materials like shredded wood waste.
- **Incentives:** Offering incentives, such as subsidies or rebates, can encourage people to mulch their gardens and landscapes. This can help offset the cost of mulch and make it a more affordable option for everyone.

IGNITE YOUR MIND

Mulch Mayhem or Masterstroke?: Is mulching a magical solution for retaining moisture and suppressing weeds, or a double-edged sword with hidden drawbacks? Weigh the evidence by dissecting scientific research and practical experiences to decide whether this popular practice deserves a thumbs up or down.

Zero Tillage

Zero tillage, also referred to as No-Tillage or Nil Tillage, entails planting crop seeds directly with drills without prior land preparation or soil disturbance, particularly in fields where previous crop stubble remains.

Significance

- **Microbial Health:** No-till farming supports the flourishing of soil organisms vital for soil health, preventing their disturbance or destruction caused by tilling.
- **Nutrient Retention:** By leaving crop residues on the surface, no-till farming ensures improved soil nutrient retention, enhancing soil fertility and overall crop growth.
- **Increased Rainwater Utilization:** No-till farming improves rainwater absorption, particularly beneficial in hot and dry climates, potentially leading to higher yields.

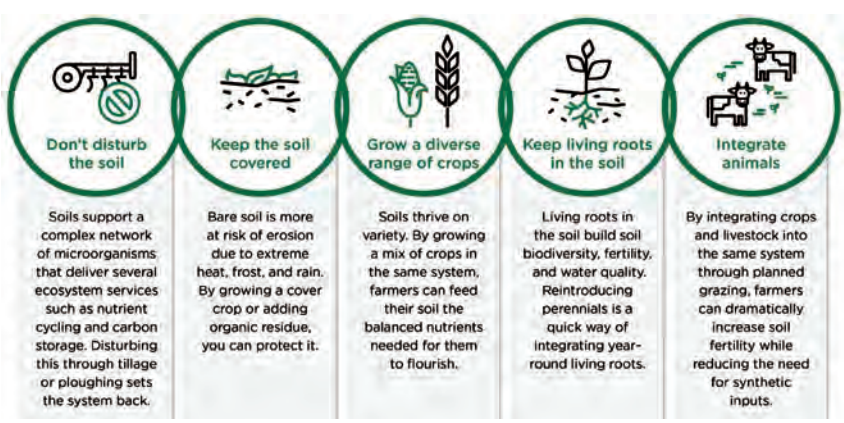

Don't disturb the soil
Soils support a complex network of microorganisms that deliver several ecosystem services such as nutrient cycling and carbon storage. Disturbing this through tillage or ploughing sets the system back.
Keep the soil covered
Bare soil is more at risk of erosion due to extreme heat, frost, and rain. By growing a cover crop or adding organic residue, you can protect it.
Grow a diverse range of crops
Soils thrive on variety. By growing a mix of crops in the same system, farmers can feed their soil the balanced nutrients needed for them to flourish.
Keep living roots in the soil
Living roots in the soil build soil biodiversity, fertility, and water quality. Reintroducing perennials is a quick way of integrating year-round living roots.
Integrate animals
By integrating crops and livestock into the same system through planned grazing, farmers can dramatically increase soil fertility while reducing the need for synthetic inputs.

Fig. 13.4: Organic No-Tillage

Challenges

- **Chemical Concerns:** The long-term effects of herbicide use on animals and humans consuming crops remain uncertain, posing potential risks to soil, air, and nearby water bodies.
- **Delayed Yield Improvements:** In certain regions, realizing the benefits of no-till farming may take time, particularly on farms left fallow for extended periods.
- **Restrictions on Grazing and Baling:** No-till farming limits the use of fields for grazing or baling grass crops, impacting livestock benefits traditionally derived from farming practices.

Way Forward

- **Research and Development:** Invest in research to develop improved zero tillage equipment and technologies suitable for various soil types and cropping systems.
- Conduct studies to assess the long-term effects of zero tillage on soil health, crop yields, and ecosystem sustainability.
- **Monitoring and Evaluation:** Establish monitoring and evaluation mechanisms to track the adoption and impact of zero tillage practices over time.

Zero Tillage in India

The practice of No-Till farming originated in India during the 1960s, initiated by local farmers. This approach **gained popularity in the Indo-Gangetic plains,** particularly in areas where rice-wheat cropping is prevalent. A key aspect of this **method involves planting wheat directly after rice harvesting, without any prior land preparation.**

IGNITE YOUR MIND

Tilling the Truth: Unearthing the Facts

Is zero tillage truly a no-till solution for sustainable farming, or are there hidden downsides lurking beneath the surface? Dig deep and unearth the truth about this popular practice, separating fact from fiction to gain a clear understanding of its potential benefits and drawbacks.

Agro-Ecology

Agroecology integrates ecological and social principles to design and manage food and agricultural systems, optimizing interactions among plants, animals, humans, and the environment while addressing social aspects for sustainability and equity.

Agro-Ecology Focuses on

- Maintaining biodiversity.
- Nurturing healthy soil.
- Minimizing external inputs (like pesticides and fertilizers).
- Promoting closed-loop systems (recycling nutrients on the farm).

Significance

- **Environmental benefits:** Reduces pollution, enhances soil health, and protects biodiversity.
- **Economic benefits:** Increases resilience to climate change, can be resource-efficient and cost-effective in the long run.
- **Social benefits:** Promotes fairer food systems, empowers farmers, can improve food security and nutrition.
- **Contextualized Solutions:** It employs bottom-up and territorial processes, providing tailored solutions to local challenges.
  - **For example,** in India, agroecological practices like System of Rice Intensification (SRI) have been successful in increasing rice yields while reducing water usage.
- **Knowledge Co-Creation:** Agroecological innovations merge scientific knowledge with traditional and local wisdom of producers.
  - **For example,** initiatives like Community Seed Banks empower farmers to conserve indigenous seed varieties and exchange knowledge.
- **Transformative Approach:** Instead of patching up unsustainable practices, it aims to overhaul food and agricultural systems, tackling root issues holistically, including social and economic dimensions.

Challenges

- **Transition Costs:** Shifting from conventional practices can involve initial investment and learning new techniques.
- **Market Access and Incentives:** Transitioning farmers may need support to access fair markets and receive incentives for sustainable practices.
- **Scaling up:** Implementing agro-ecology at a larger scale requires changes in policy, research, and education systems.

Way Forward

- **Investment and Support:** Public and private investments are needed to support research, education, and infrastructure for agroecological practices.
- **Consumer Awareness and Demand:** Educating consumers about the benefits of agroecology can increase demand for sustainably produced food.
- **Collaboration:** Collaboration among farmers, researchers, policymakers, and consumers is crucial for creating a supportive environment for adopting agroecology on a broader scale.

Zero Budget Natural Farming (ZBNF)

Zero Budget Natural Farming (ZBNF) is an inventive agricultural approach that breaks away from conventional methods by eliminating the need for external inputs like chemical fertilizers and pesticides. It was Introduced by agriculturist **Subhash Palekar** in the mid-1990s, ZBNF has become a sustainable and cost-effective substitute for Green Revolution-driven practices.

Zbnf Promotes Several Natural Farming Practices

- **Jivamrita/Jeevamrutha:** A fermented microbial culture that enriches the soil with nutrients, stimulates microbial activity, and enhances earthworm activity, while also providing protection against fungal and bacterial diseases in plants.
- **Bijamrita:** This mixture safeguards young roots from soil-borne and seed-borne diseases effectively. Prepared from a blend of desi cow dung, urine, jaggery, among other ingredients, it contributes to plant health and vitality.
- **Acchadana/Mulching:** Involves laying a protective layer of biomass on the soil surface, which helps in retaining moisture, suppressing weed growth, and improving soil structure and fertility.
- **Whapasa/Moisture Management:** Whapasa ensures the presence of both air and water molecules in the soil, promoting optimal soil moisture conditions. ZBNF advocates reducing irrigation and watering only at noon in alternate furrows to conserve moisture effectively.

Difference between Zero Farm Budgeting and Conventional Farming

Zero Budget Natural Farming	Conventional Farming
Almost zero cost.	High input and operational cost.
Jeevamrutha and other methods applied here.	Fertilizers are used.
No ploughing tilting needed.	Ploughing and tilting needed.
GMO not used here.	GMO used here.
Less irrigation requirement.	Intensive Irrigation.
Based on ecological condition.	Based on economic condition.

Significance

- **Improved Crop Productivity and Soil Fertility:** ZBNF enhances crop yields and soil fertility through atmospheric nitrogen fixation, without relying on synthetic fertilizers. For example, farmers practicing ZBNF in Andhra Pradesh, India, have reported significant increases in yields of crops like paddy, millets, and pulses.
- **Cost Reduction for Farmers:** By utilizing cow dung, urine-based formulations, and botanical extracts, ZBNF reduces input costs, making farming more economically sustainable. Farmers in Karnataka, India, practicing ZBNF have reported up to 30% reduction in input costs compared to conventional farming methods.
- **Healthier Food Production:** ZBNF eliminates the use of chemical fertilizers, resulting in crops free from harmful residues, thus promoting healthier food production and reducing health risks.
- **Empowerment and Employment Generation:** Adoption of ZBNF can create employment opportunities in agriculture and allied sectors, particularly empowering women and contributing to rural livelihoods. In Telangana, India, the implementation of ZBNF has led to the formation of women-led Self Help Groups (SHGs) engaged in seed conservation and organic farming activities.
- **Environmental Sustainability:** ZBNF prevents soil degradation, salination, and water contamination, ensuring sustainable land and water resources and minimizing the environmental footprint of agriculture.

Challenges

- Experts question the effectiveness of ZBNF in addressing agrarian challenges in India, citing limited testing on diverse soil types.
- Agrarian distress persists due to escalating input expenses, inadequate MSPs, and stagnant prices.
- Challenges from conventional farming methods, such as knowledge gaps, seed bank availability, cold chain facilities, MSPs, and marketing issues, remain unresolved.

Way Forward

- The government needs to take proactive steps to narrow the knowledge gap and facilitate access to inputs.
- Establishment of local markets is essential to ensure farmers receive fair prices for their harvest.
- Providing cash incentives to farmers adopting practices like “yogik” farming and “gou mata kheti” can encourage the adoption of zero budget natural farming.
- Initiatives such as Rashtriya Krishi Vikas Yojana and Parampargat Krishi Vikas Yojana can be tailored to support the implementation of zero budget farming.

National Mission on Natural Farming (NMNF), also known as Bharatiya Prakritik Krishi Paddhati Programme (BPKP), operates as a sub-mission under the Paramparagat Krishi Vikas Yojana (PKVY) within the framework of the National Mission on Sustainable Agriculture (NMSA).

- Its duration spans **six years, from 2019-20 to 2024-25, aiming to promote natural farming** practices throughout India.
- The program follows a demand-driven approach, requiring states to formulate long-term perspective plans with year-wise targets and objectives.
- The National Institute of Agricultural Extension Management **(MANAGE)** serves as the knowledge partner for extending natural farming practices.
- The National Centre of Organic and Natural Farming **(NCONF)** focuses on developing certification programs, establishing a certification management secretariat, and integrating portals to facilitate effective management and maintenance.

Organic Farming

Organic farming entails cultivating land and nurturing crops using natural methods. Its goal is to maintain soil vitality and wellness by incorporating organic materials like crop residues, animal manure, and beneficial microorganisms, fostering nutrient release for sustainable and eco-friendly crop production, devoid of pollution.

(add content)

Fig. 13.5: Organic Farming

Concepts of Organic Farming

- **Traditional Practice:** Organic farming has been a way of life and a tradition in our Indian farming system for centuries; it is not a new concept.
- **Pest and Disease Management:** Organic farming has its own system for controlling pests and diseases in crop and livestock production, which avoids the use of various synthetic chemicals or gene manipulation.
- **Foundation in Natural Laws:** Organic farming is based on an intimate understanding of nature's laws and rules.
- **Sustainable Nutrient Management:** They release nutrients to increase crop yield and sustainability. "Organic agriculture is a production system that promotes the health of soils, ecosystems, and people."

Comparison with Zero Budget Natural Farming

Similarities

- Both organic and natural farming practices are considered sustainable agriculture methods.
- They aim to produce chemical-free foods by avoiding synthetic fertilizers and chemical pesticides.
- Both emphasize the use of local seed varieties and homemade pest control methods.

Differences

Aspect	Organic Farming	Natural Farming (ZBNF)
Intervention Approach	Holistic system optimizing productivity (e.g., ploughing, tilling).	Minimal intervention to preserve natural agroecosystem.
Handling of Agroecosystem	Incorporates diverse communities (plants, livestock).	Emphasizes preservation of natural agroecosystem.
Practices	Supports conventional practices like ploughing, tilling, etc.	Avoids practices such as ploughing, tilling, and manuring.
Cost	Can be capital-intensive due to bulk organic manures.	Extremely low-cost, often zero, utilizing locally made preparations.

Significance

- **Expanding Market Opportunities:** High demand for organic products in India and globally leads to increased export revenue.
- **Health and Nutritional Benefits:** Organic products are more nutrient-dense, palatable, and healthier compared to those produced with chemicals and fertilizers.
- **Environmental Advantages:**
  - Organic farming, free of fertilizers and chemicals, has no negative environmental impact.
  - Supports increased wildlife presence, particularly in lowlands with ample grazing opportunities.

Case Study: The Sri Lankan Crisis and Organic Farming

In 2021, Sri Lanka experienced a severe economic crisis, leading to food shortages, inflation, and social unrest. While the crisis had multiple contributing factors, the government's sudden and poorly implemented shift towards organic farming played a significant role in exacerbating the situation.

In April 2021, the government abruptly banned all imports of chemical fertilizers and pesticides, aiming to save foreign exchange, promote sustainability, and provide citizens with "non-toxic food."

Challenges

- **Unpreparedness:** Sri Lanka lacked a robust domestic organic fertilizer industry and infrastructure. Farmers struggled to find or afford alternative organic options, leading to significant drops in crop yields (rice production fell nearly 50%).
- **Economic Impact:** Lower yields translated to food shortages, higher food prices, and a decline in export earnings. This, coupled with the pandemic and the pre-existing economic crisis, caused severe hardship for many Sri Lankans.

- **Social Unrest:** Food insecurity and rising prices fueled public discontent, leading to protests and contributing to the political instability that ultimately resulted in the president's resignation.

Conclusion

The Sri Lankan crisis offers valuable lessons for policymakers and stakeholders contemplating similar shifts in agricultural practices. A balanced approach that acknowledges the potential benefits and drawbacks of organic farming, coupled with thorough planning, infrastructure development, and support for farmers, is necessary to ensure a successful and sustainable transition.

Challenges

- **Limited Availability:** Organic manure is not widely accessible, and if purchased, organic inputs may be more expensive than chemical fertilizers in terms of plant nutrients.
- **Complexity of Guidelines:** Guidelines for organic production, processing, transportation, and certification are complex and challenging for the average Indian farmer to comprehend.
- **Certification Hurdles:**
  - Many farms in India, either never chemically managed or returning to organic farming, are not formally recognized as organic.
  - The costs and extensive documentation required for certification deter many farmers from seeking certification.

IGNITE YOUR MIND

Greener Pastures: Beyond the Chemical Maze

Sustainable agriculture transcends mere yield maximization. Explore diverse landscapes of innovative production practices for both plant and animal agriculture, venturing beyond the reliance on harmful chemicals and unsustainable methods.

Initiatives Taken

Global Level

- **International Federation of Organic Agriculture Movements (IFOAM):** This global network of organizations advocates for organic farming and provides resources and certification programs for organic producers.
- **European Union's (EU) Organic Action Plan:** The EU aims to increase organic farmland to atleast 25% by 2030 and provide financial support and research funding for organic farming initiatives.
- **Food and Agriculture Organization (FAO):** The FAO helps member countries improve their capacity in organic production, processing, certification, and marketing.

National Level

- **Mission Organic Value Chain Development in the North East Region (MOVCD-NER)**
  - MOVCD-NER, a Central Sector Scheme, falls under the National Mission for Sustainable Agriculture (NMSA) and was initiated in 2015 by the Ministry of Agriculture and Farmers Welfare.
  - The primary objective is to foster certified organic production through a value chain approach, facilitating the connection between growers and consumers while bolstering the entire value chain's development.
- **Paramparagat Krishi Vikas Yojana (PKVY)**
  - It promotes organic farming via a cluster-based approach in organic villages and the adoption of the Participatory Guarantee System (PGS) certification.
- **Certification Schemes:**
  - The Food Safety and Standards Authority of India (FSSAI) regulates food in the nation, including organic food both domestically and for imports.
  - The Participatory Guarantee System (PGS) certifies organic products, ensuring compliance with quality standards.
  - PGS Green certification applies to chemical-free produce during the three-year transition to full "organic" status, primarily for domestic use.
  - The National Program for Organic Production (NPOP) offers organic farming certification for export purposes through a third-party certification process.

Way Forward

- **Scaling up:** Expanding organic land area and production to meet growing demand requires infrastructure development, efficient supply chains, and financial support for farmers transitioning to organic practices.
- **Market Access and Fair Prices:** Facilitating access to organic markets, ensuring fair prices for producers, and raising consumer awareness of the value proposition of organic food are crucial.
- **Research and Development:** Continuous research on organic farming methods, pest management, and seed variety development are essential for enhancing productivity and resilience.

Permaculture

Permaculture is a design system derived from "permanent agriculture" or "permanent culture," aimed at creating sustainable human environments. It entails designing integrated systems for food production, housing, appropriate technology, and community development rooted in ecological principles.

Key Principles Behind Permaculture

- **Comprehensive Methodology:** Permaculture offers a holistic approach to system analysis and design.
- **Ecosystem Restoration:** It aids in creating productive ecosystems and restoring degraded ones.
- **Universal Applicability:** Permaculture can be applied in any ecosystem, regardless of its condition.
- **Respect for Traditional Knowledge:** Traditional wisdom is valued and integrated into permaculture practices.
- **Cultural Integration:** It serves as a bridge between traditional and emerging earth-centered cultures.

Significance

- **Enhancing Biodiversity and Wildlife Protection:** Permaculture contributes to biodiversity enhancement and wildlife protection by addressing soil fertility, water conservation, climate change mitigation, and habitat provision.
- **Synergistic Plant Combinations:** Permaculture incorporates a mix of perennial and annual plants that support each other's nutritional needs, reducing reliance on chemical inputs like fertilizers, pesticides, and herbicides.
- **Space Conservation and High Output:** Permaculture is effective for designing compact spaces with high productivity, facilitating space conservation efforts.
- **Additional Benefits:** Permaculture promotes better health outcomes, mitigates water shortages, reduces pollution, and decreases risks for farmers by moving away from monoculture dependency.

Challenges

- **Short-Term Losses for Farmers:** Farmers may face short-term setbacks due to the initial investment and the time required to see tangible results from permaculture practices.
- **Uncertain Crop Yields:** Permaculture's reliance on new methods and uncertain crop yields can be problematic for nations dependent on consistent agricultural yields for food security.
- **Risk of Food Shortages:** If permaculture fails to deliver expected yields, it could have severe repercussions on local food availability and exacerbate food insecurity.

Way Forward

- **Awareness:** Increase education and awareness programs to promote understanding and acceptance of permaculture principles among farmers, policymakers, and communities.
- **Research and Development:** Invest in research and development to enhance permaculture techniques, improve crop yields, and address challenges such as pest management and soil fertility.
- **Policy Support:** Develop supportive policies and incentives at local, national, and international levels to encourage the adoption of permaculture practices and facilitate the transition away from conventional agriculture.

The Sustainable Sugarcane Initiative (SSI) comprises innovative agronomic practices aimed at enhancing cane yields substantially. **These practices include** reducing seed usage, cultivating seeds in a nursery, and implementing novel planting techniques with increased seed spacing, alongside improved water and nutrient management.

- The techniques of the Sustainable Sugarcane Initiative (SSI) have the potential to boost sugarcane yields by a minimum of 20%, while also **reducing water usage by 30%** and cutting down chemical inputs by 25%.
- Derived from the 'More with Less' philosophy observed in the System of Rice Intensification (SRI), the SSI approach to sugarcane cultivation was introduced in India through a collaborative project between WWF and ICRISAT in 2009.

Vertical Farming Systems

Vertical farming involves growing crops in vertical, stacked layers instead of horizontally on the ground, conserving land and water resources, particularly in areas where they are scarce. It employs soilless farming techniques, such as hydroponics and aeroponics, where plants grow without soil, directly in water or mist.

Types of Vertical Farming Systems

- **Hydroponics:** It is a method of plant cultivation that utilizes a water-based, nutrient-rich solution instead of soil.
  - **Root Support:** Plants in hydroponic systems are grown with their root systems supported by inert mediums such as perlite, clay pellets, or peat moss.
  - **Oxygen Access:** The primary purpose of the inert medium is to provide support for the plants while allowing access to oxygen, essential for proper root growth and function.
- **Aeroponics:** Aeroponics is an environmentally friendly farming technique where plants are grown without soil, with their roots suspended in the air.
  - **Growing Environment:** Unlike hydroponics, aeroponics eliminates the use of both growing medium and flowing water. Instead, plants' roots are periodically misted or sprayed with a nutrient-rich water solution.
  - **Controlled Environment:** Aeroponics allows for precise control of environmental factors such as humidity, temperature, pH levels, and water conductivity within a controlled greenhouse setting.
- **Aquaponics:** It integrates hydroponics and aquaculture in a closed-loop system, fostering a symbiotic relationship between plants, fish, and bacteria.

- **Biological Components:** The aquaponics system consists of three main biological components: fish, plants, and beneficial bacteria.
- **Symbiotic Relationship:** Fish waste serves as fertilizer for plants, providing essential nutrients. In return, plants purify the water for the fish, creating a mutually beneficial ecosystem.

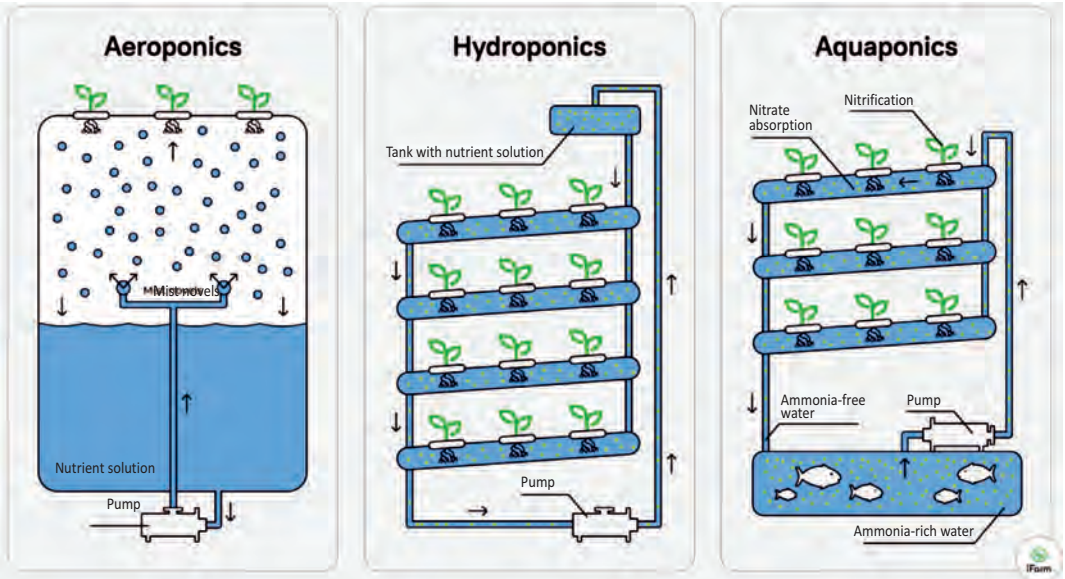


Fig. 13.6: Vertical Farming Systems

Significance of Vertical Farming System

- **Water Efficiency:** Vertical farming achieves over 95% water efficiency, conserving water compared to traditional methods, crucial in a country like India with limited water resources.
- **Impact on Water Scarcity:** Vertical farming can enhance food productivity while drastically reducing water usage, aligning with India's goals of carbon-neutrality in food production.
- **Circular Economy Benefits:** Techniques like cocoponics turn agricultural residues into compost, creating new revenue streams, especially for farmers in rural areas, while combating soil degradation.
- **Public Health:** Vertical farming produces pesticide-free crops, promoting public health with fresh and sustainable produce.
- **Job Creation:** Protected cultivation, including vertical farming, can generate new jobs and economic opportunities, particularly benefiting agriculture students and fostering innovation in the agricultural sector.

Challenges

- **Elevated Energy Expenditure:** Vertical farming entails significant energy costs, primarily due to the reliance on artificial lighting for plant growth.
- **Potential Water Contamination:** Excessive nutrient usage in vertical farming may pose a risk of contaminating the urban water system if proper precautions are not taken.
- **Heat Emission from LED Lighting:** LED lighting systems, while efficient, emit heat that could pose challenges in temperature management, particularly during summer months. This may lead to increased energy consumption for air conditioning, further driving up operational costs.

Way Forward

- **Food Security with Soilless Techniques:** Government support should make aeroponics and hydroponics affordable through subsidies, ensuring a broader adoption for enhanced food production.
- **Skill Development for Soilless Farming:** Establish training initiatives to impart specialized knowledge, enabling safe and effective implementation of soilless techniques, such as workshops for farmers.
- **Sustainable Farming Shift:** In countries like India, promote aeroponics and hydroponics to counter land pressure and highlight successful case studies to encourage wider adoption.

Vertical farming presents a viable solution to pressing issues encountered in Indian agriculture, such as inadequate or surplus supply of agricultural produce, excessive pesticide and fertilizer usage, soil degradation, and unemployment.

Integrated Pest Management (IPM)

Integrated Pest Management (IPM) is an ecological approach aimed at preventing pests or their harm over the long term. It employs various methods including biological control, habitat adjustment, cultural practice modification, and resistant crop varieties. Pesticides are utilized only when monitoring indicates their necessity as per established standards, and treatments are targeted specifically at the intended pest.

Integrated Pest Management Components

- **Biological Control:** This method involves harnessing natural enemies such as predators, parasites, pathogens, and competitors to regulate pest populations and mitigate their impact. Various organisms including invertebrates, plant pathogens, nematodes, weeds, and vertebrates have numerous natural adversaries.
- **Cultural Controls:** Cultural practices aim to diminish pest establishment, reproduction, dispersal, and survival. For instance, adjusting irrigation techniques can mitigate pest issues by preventing excess moisture, which can lead to root diseases and weed proliferation.
- **Mechanical and Physical Controls:** These strategies directly eliminate pests, obstruct their access, or create an unfavorable environment for their existence. Examples include rodent traps as a mechanical measure and mulches for weed management, soil steam sterilization to manage diseases, or barriers like screens to deter birds or insects.
- **Chemical Control:** Chemical control involves the use of pesticides. In Integrated Pest Management (IPM), pesticides are employed judiciously and in conjunction with other methods for optimal, sustainable pest management. Pesticides are chosen and applied in a manner that minimizes potential harm to humans, non-target organisms, and the environment.

Significance of Integrated Pest Management (IPM)

- **Biological Control:** Utilizes natural predators, parasites, or pathogens. **Example:** Introducing ladybugs for aphid control.
- **Cultural Practices:** Modifies agricultural methods to reduce pest impact. **Example:** Implementing crop rotation strategies.
- **Mechanical and Physical Control:** Deploys physical barriers or traps for pest removal. **Example:** Using row covers to shield plants.
- **Chemical Control:** Prudent use of pesticides as a last resort. **Example:** Opting for environmentally friendly pesticides.
- **Monitoring and Decision-Making:** Regularly assesses pest populations for timely interventions. **Example:** Using monitoring data to guide control measures.

Challenges in IPM Implementation

- **Resistance:** Pests developing resistance to insecticides. **Solution:** Developing new control methods and rotating strategies.
- **Knowledge and Training:** Need for expertise in pest biology and control. **Solution:** Training farmers and professionals in IPM practices.
- **Costs and Economics:** Some IPM practices are initially more expensive. **Solution:** Demonstrating long-term economic benefits for sustainability.
- **Resistance to Change:** Farmers and professionals are reluctant to adopt new practices. **Solution:** Education, outreach, and incentives to overcome resistance.

Way Forward for IPM

- **Research and Innovation:** Ongoing research into alternative pest control methods.
  - **Example:** Developing pheromone traps and resistant crop varieties.
- **Education and Training:** Training programs covering pest identification and monitoring techniques.
  - **Focus:** Equipping stakeholders with ecological concepts for effective IPM.
- **Policy Support:** Government policies incentivizing sustainable pest control.
  - **Actions:** Subsidies for IPM training, tax incentives, and regulations on harmful pesticides.
- **Integration of Technologies:** Utilizing precision agriculture and data analytics.
  - **Impact:** Enhancing IPM effectiveness through targeted control measures.
- **Collaboration and Partnerships:** Cooperative efforts among farmers, researchers, and agencies.
  - **Goal:** Facilitating knowledge sharing and coordinated action for successful IPM implementation.

The primary objective of the **Insecticides Act of 1968** was to govern the import, production, sale, transportation, distribution, and application of insecticides and pesticides, aiming to mitigate potential hazards to humans and animals.

Other Sustainable Agricultural Practices

- **Crop Rotation and Diversity:** By rotating crops and fostering diversity in planting, farmers can enhance soil health and improve pest control. Techniques like intercropping and multi-year crop rotations contribute to these practices.
- **Cover Crop Implementation:** Planting cover crops such as clover or hairy vetch during off-season periods protects soil, prevents erosion, enriches soil nutrients, and suppresses weeds, reducing the need for herbicides.
- **Integration of Livestock and Crops:** Instead of keeping plant and animal production separate, sustainable farming integrates livestock with crops. This approach, contrary to industrial agriculture, utilizes animal manure fertilizers efficiently, leading to more efficient and profitable farms.
- **Holistic Management of Systems and Landscapes:** Sustainable farming considers uncultivated or less intensively cultivated areas integral to the farm's ecosystem. Riparian buffers and prairie strips are valued for their role in erosion control, nutrient runoff reduction, and support for pollinators and biodiversity.

Sustainable Aspects of Indian Agriculture

- **Agroforestry Integration:** Increasingly, Indian farmers are embracing the practice of integrating trees with crops, which enhances soil health, biodiversity, and provides supplementary income streams.
- **Rise of Organic Farming:** There is a noticeable shift towards organic farming methods in India, aimed at reducing reliance on chemical inputs, preserving soil health, and producing nutrient-rich food.
  - **Example:** According to the Ministry of Agriculture & Farmers' Welfare, the area under organic cultivation in India has grown by 50% over the past five years.
- **Water Conservation Practices:** Adoption of water-saving techniques such as drip irrigation, rainwater harvesting, and precision agriculture is on the rise, enhancing water efficiency and alleviating pressure on groundwater resources.
- **Local Food Movements**: The burgeoning awareness regarding the benefits of consuming local, seasonal produce is fostering biodiversity conservation and reducing carbon emissions associated with long-distance transportation.
- **Government Initiatives:** Various government schemes like the Soil Health Card and Paramparagat Krishi Vikas Yojana are actively promoting sustainable agricultural practices and empowering farmers with necessary resources.
  - **Example:** As per the Ministry of Agriculture & Farmers' Welfare, over 150 million Soil Health Cards have been distributed to farmers across India since the launch of the program.

Sustainable Agriculture Advantages

- **Environmental Protection:** Sustainable agriculture prioritizes techniques that enhance soil productivity while minimizing negative impacts on the environment, including air and water quality, biodiversity, and climate stability.
  - **Example:** Practices like crop rotation, cover cropping, and agroforestry help improve soil health and reduce erosion.
- **Energy Conservation:** It focuses on reducing reliance on petroleum-based products and other non-renewable resources, promoting the use of renewable alternatives to save energy.
  - **Example:** Solar-powered irrigation systems and biofuels derived from agricultural waste minimize energy consumption.
- **Food Security:** Sustainable agriculture aims to meet the present and future generations' dietary needs, ensuring both the quantity and quality of food production.
  - **Example:** Techniques such as diversified cropping systems and improved seed varieties contribute to resilient food systems capable of withstanding environmental challenges.
- **Economic Profitability:** It not only increases agricultural output sustainably but also reduces vulnerability to economic risks such as price fluctuations, enhancing the sector's long-term economic viability.
  - **Examples:** Include direct marketing channels like farmers' markets and community-supported agriculture (CSA), which provide farmers with stable incomes and consumers with access to fresh, locally produced food.
- **Economic and Social Equity:** Sustainable agriculture endeavors to provide stable employment, fair wages, and decent living and working conditions for all involved in the agricultural value chain, promoting economic and social equity.
  - **Example:** Initiatives such as fair trade certification and cooperative farming models empower small-scale farmers and support equitable distribution of resources.
- **Community Integration:** It emphasizes the importance of considering local demands, knowledge, skills, sociocultural values, and institutional structures, fostering community integration and resilience. Community-supported agriculture programs, where consumers buy shares of a farm's harvest in advance, promote collaboration between farmers and consumers while supporting local food systems.

Challenges with Sustainable Agriculture

- **Organic Farming and Food Security:** With the world's population continuing to grow, there is increasing concern about our ability to sustain current population levels.
  - Transitioning to organic farming often leads to significant yield declines compared to intensive farming, necessitating integration with other sustainable production methods to meet global food needs.
- **Feasibility of Conservation Agriculture for Soil Management:** Conservation agriculture, which eliminates plowing, requires adjustments in weed control practices, herbicide use, and specialized sowing equipment.
  - Its adoption by smallholders in developing countries is challenging, with most implementation concentrated in North America, Europe, and Australia.
- **Issues with Small Land Holdings:** While many argue that small-scale cultivation is more environmentally friendly than industrial models, smallholders may harm soil and ecosystems due to limited access to modern sustainable farming methods and knowledge.

- **Debate on High-Yield Variety (HYV) Seeds Usage:** High-yielding hybrid seeds are seen as risky for human and environmental health and economically unsustainable for farmers. However, given concerns about food security, they remain essential for boosting agricultural output.
- **Use of Chemical Pesticides:** Complete elimination of chemical pesticides may not be feasible due to increasing insect infestations and crop loss. Instead, reducing reliance on chemical pesticides and using less toxic alternatives is recommended.

Constraints to Sustainable Agriculture in India

- **Population Growth and Ecosystem Degradation:** With a rising population and deteriorating ecosystems, traditional farming methods and deforestation persist. For instance, the expansion of agriculture into forested areas continues due to population pressure.
- **Limited Capital:** Small and medium farmers face financial constraints when attempting to shift towards sustainable agriculture.
  - **For example,** lack of access to credit prevents many farmers from investing in organic farming practices.
- **Access to Information & Technology:** The absence of agricultural knowledge and technology hampers the adoption of sustainable practices. For instance, remote rural areas often lack access to extension services and modern farming techniques.
- **Lack of Economic Incentives:** Farmers hesitate to embrace sustainable farming due to uncertainties about its economic viability.
  - **For example,** without government subsidies or price incentives, farmers may see little financial benefit in transitioning to organic methods.
- **Insufficient Policy Support & Infrastructure:** Inadequate policies and infrastructure pose barriers to the widespread adoption of sustainable agriculture. For instance, the lack of rural roads and storage facilities hinders farmers' ability to access markets and sell their produce at fair prices.

Initiatives to Promote Sustainable Agriculture

Global Initiatives

- **Green Ag Project**
  - The government, in collaboration with the Food and Agriculture Organization (FAO), has initiated a project called "Green-Ag: Transforming Indian Agriculture for global environment benefits and the conservation of critical biodiversity and forest landscapes." This project is supported by the Global Environment Facility (GEF) and is being implemented in high-conservation-value landscapes across five states.
  - The objective is to implement sustainable land and water management practices on a minimum of 104,070 hectares of farmland and achieve a reduction or sequestration of 49 million carbon dioxide equivalents through sustainable land use and agricultural practices.
- **Global Alliance for Climate-Smart Agriculture:** The initiative was inaugurated on September 23, 2014, during the UN Climate Summit. It is a collaborative and participatory initiative focused on Climate-Smart Agriculture (CSA), engaging various stakeholders voluntarily in practical actions.
- **Global Initiative of Sustainable Agriculture and Environment:** Promotes innovative farming and farm management practices that use natural resources to increase farm productivity, food quality, and environmental health.
- **Sustainable Agriculture and Land Health Initiative:** A two-year initiative that aims to build commitments for sustainable agriculture that secures land health.
- **Sustainable Agriculture Initiative (SAI) Platform:** Involves all food chain stakeholders in the development and implementation of sustainable agricultural practices.

Indian Initiatives

- **National Mission on Sustainable Agriculture (NMSA)**
  - The National Mission for Sustainable Agriculture (NMSA) seeks to enhance agricultural productivity, sustainability, profitability, and resilience to climate change. This is achieved through the promotion of location-specific integrated/composite farming systems, soil and moisture conservation measures, comprehensive soil health management, efficient water management practices, and the incorporation of rainfed technologies into mainstream agricultural practices.
  - **The National Mission for Sustainable Agriculture (NMSA) includes four major programs:**
    - RAD (Rainfed Area Development), emphasizing integrated development in rainfed areas;
    - OFWM (On-Farm Water Management), promoting water conservation through advanced technologies and farm pond construction;
    - SHM (Soil Health Management), implementing tailored practices for soil preservation and fertility enhancement;
    - and CCSAMMN (Climate Change and Sustainable Agriculture: Monitoring, Modeling, and Networking), disseminating climate change knowledge for informed agricultural decisions.

❑ **Soil Health Card (SHC) Scheme**

SOIL HEALTH CARD SCHEME
IMPROVING SOIL FERTILITY SUSTAINABLY
The card will carry crop wise recommendations of nutrients/ fertilizers required for farms
State governments to set up Soil Testing Laboratories for issuing Soil Health Cards
It will help farmers to improve productivity by using appropriate inputs
Involvement of agricultural students, NGOs & private sector in determining average soil health of villages

Fig. 13.7: Soil Health Card Scheme

- The Soil Health Card Scheme was launched by the Government of India on February 19, 2015.
- Under this initiative, farmers receive soil health cards containing customized recommendations for nutrients and fertilizers tailored to their individual farms, facilitating enhanced productivity through judicious input management.

❑ **Paramparagat Krishi Vikas Yojana (PKVY):** The PKVY program seeks to promote commercial organic farming by involving clusters of certified organic farmers, encouraging cluster farming practices.

❑ **Network Project on Organic Farming of ICAR:** The ICAR's Network Project on Organic Farming aims to assess the comparative performance of different agricultural systems under organic and conventional farming methods, evaluating the agronomic efficacy of diverse production techniques.

❑ **Sustainable Sugarcane Initiative (SSI):** The SSI strategy aims to enhance sugarcane yields by optimizing seed usage, water efficiency, and fertilizer and land utilization.

❑ **System of Rice Intensification (SRI):** This agroecological approach alters rice cultivation practices to increase yields through improved management of plants, soil, water, and nutrients. Variations such as the Kadiramangalam System of Rice Intensification are utilized in specific regions like the Indian Cauvery delta, employing younger seedlings and spaced planting for efficient water use.

Way Forward

❑ **Appropriate Production Systems:**

- Aligning agricultural policies with agro-ecological resources is crucial for sustainability.
- For instance, in arid and semi-arid regions, promoting dry land agriculture over input-intensive methods and emphasizing less water-intensive crops like pulses and millets is essential.
- Similarly, relocating water-intensive crops such as rice to regions with more abundant water resources is advisable.

❑ **Polycultures and Crop Rotation:**

- Transitioning farmers from monocultures to polycultures and crop rotation can decrease the reliance on fertilizers and pesticides.
- Diverse agricultural systems are typically more productive, labor-intensive, and offer enhanced ecosystem services, thus promoting sustainability.

❑ **Emphasis on Soil Nurturing:** Prioritizing soil health over plant health can lead to sustained yields, improved ecosystem vitality, and carbon sequestration, offering greater long-term benefits.

❑ **Promotion of Zero Budget Natural Farming:** Initiatives like Zero Budget Natural Farming, which entail minimal external inputs and production costs, have the potential to restore ecosystem health and diversify smallholder farmers' incomes.

❑ **Reducing Food Waste and Promoting Sustainable Consumption Patterns:** Addressing food waste requires investments in post-production infrastructure, including rural storage facilities, as well as improvements in harvesting and transportation practices to promote sustainable consumption patterns.

Sustainable agriculture must integrate social, economic, and environmental aspects to be effective. Given the increasing population, diminishing resources, and escalating climate change risks, transitioning to sustainable food and agricultural systems is imperative. These systems must ensure global food security, foster economic and social development, and safeguard the ecosystem services vital for our future.

Contemporary Topics in News

Urban Agriculture

Urban agriculture (UA) encompasses agricultural activities within urban and peri-urban areas, which are transitioning zones between urban and rural environments. The Food and Agricultural Organization's (FAO) Urban Food Agenda aims to promote sustainable development, food security, and nutrition in these areas.

In recent times urban and peri-urban areas worldwide are estimated to have produced between 15-20% of all food.

Significance of Urban Agriculture

- **Food and Nutritional Security:** With just 5% of urban areas in India, approximately 222 million urban residents could be served, enhancing food security and nutrition.
- **Resilience of Food Supply:** UA reduces the distance from farm to fork, providing fresh produce to city dwellers and enhancing the city's food supply resilience.
- **Environmental Management:** It aids in combating urban heat island effects, reducing carbon emissions, and contributing to environmental sustainability.
- **Waste Management:** Organic waste can be composted and utilized in food production, reducing the burden on landfills and promoting waste management.
- **Job Opportunities and Land Utilization:** UA creates job opportunities, utilizes underutilized lands efficiently, and contributes to economic growth.

Challenges

- Constraints to UA include limited access to land due to high rents, water shortages resulting from high water demand, and the lack of recognition and support for UA practices.
- Additionally, the use of pesticides and harmful chemicals can lead to pollution of soil, water, and air.

Initiatives in India

- **Pune:** In 2008, Pune's civic administration initiated a city farming project aimed at training and encouraging individuals to engage in farming on designated land.
- **Kerala:** Kerala, previously food-dependent, launched a vegetable development program in 2012 to promote gardening in households, schools, and public institutions.
- **Tamil Nadu:** In 2014, the Tamil Nadu government introduced a "do-it-yourself" kit under its Urban Horticulture Development Scheme. This initiative aimed to enable city dwellers to cultivate vegetables on rooftops, houses, and apartment buildings.

Way Forward

- To address these challenges, raising awareness about the benefits of UA, utilizing community spaces, and promoting UA under existing schemes like PMSA are recommended.
- Moreover, leveraging technological advancements such as precision farming and vertical farming can enhance resource efficiency in UA practices.

Climate Smart Agriculture

The Food and Agriculture Organization of the United Nations (FAO) defines Climate-Smart Agriculture (CSA) as agricultural practices that aim to boost productivity sustainably, improve resilience (adaptation), decrease or eliminate greenhouse gas emissions (mitigation) where feasible, and contribute to achieving national food security and development objectives.

Three Pillars

- **Production Focus:** CSA aims to enhance agricultural productivity and income derived from crops, livestock, and seafood while minimizing adverse environmental impacts. This will lead to improved food and nutritional security.
  - **Sustainable Intensification:** Emphasizing sustainable intensification is crucial for increasing production sustainably.
- **Adaptation Strategy:** CSA endeavors to reduce farmers' vulnerability to short-term risks and enhance their resilience to adapt and thrive amid both immediate shocks and long-term challenges.
  - **Protection of Ecological Services:** Special attention is given to safeguarding the ecological services provided by ecosystems to farmers and others, as these services are essential for sustaining production and adapting to climate change.
- **Mitigation Efforts:** CSA aims to reduce or eliminate greenhouse gas (GHG) emissions wherever possible, striving for emission reductions for every unit of food, fiber, and fuel produced. Preventing agricultural deforestation and optimizing the capacity of soils and trees to act as carbon sinks are key mitigation strategies.

Significance

- **Integration of Climate Change:** Unlike conventional agricultural development, CSA deliberately incorporates climate change considerations into the design and development of sustainable agricultural systems.
- **Protection of Ecological Services:** CSA recognizes the importance of ecosystems in providing essential services such as clean air, water, food, and materials, thereby safeguarding ecological services vital for agricultural sustainability.

- **Multiple Access Points:** CSA provides various entry points, including technological advancements, climate change modeling, information technology, insurance schemes, value chains, and institutional and political frameworks enhancement, rather than being limited to specific activities or technologies.
- **Context-Dependent Approach:** CSA acknowledges that what may be considered climate-smart in one area may not be applicable in another, emphasizing that no single action is universally climate-smart at all times.
- **Inclusion of Marginalized Groups:** CSA initiatives prioritize the inclusion of the poorest and most vulnerable populations, particularly women and marginalized groups, to achieve food security goals and enhance resilience, as they are often disproportionately affected by climatic events such as droughts and floods.

Challenges

- **Knowledge and Skill Gaps:** Small-scale and resource-poor farmers often lack access to current information and technical skills needed for climate-smart practices, hindering adoption.
- **Financial Constraints:** Limited financial resources pose a barrier to implementing climate-smart agriculture, as upfront investments in new technologies and infrastructure are often required.
- **Policy and Institutional Barriers:** Inadequate policy frameworks and weak institutional support impede the uptake of climate-smart agriculture, along with lack of cooperation among government agencies and unclear land tenure systems.
- **Uncertain Climate Projections:** Uncertainty in climate change projections and regional climatic variability make it challenging for farmers to make informed decisions and adapt their practices.
- **Limited Access to Resources:** Farmers face difficulties accessing essential resources like land, water, seeds, and fertilizers, with climate change exacerbating resource scarcity.
- **Technological Compatibility and Scalability:** Not all climate-smart agricultural technologies and practices are suitable for all agro ecological zones or farming systems, requiring context-specific approaches and innovation.

Government Initiatives

- **National Innovations on Climate Resilient Agriculture (NICRA):** Launched in 2011, it is a collaborative project initiated by the Indian Council of Agricultural Research (ICAR). Its Objectives are as follows:
  - **Enhancing Agricultural Resilience:** The project aims to bolster the resilience of Indian agriculture, encompassing crops, livestock, and fisheries, against climatic variability and climate change by developing and implementing advanced production and risk management technologies.
  - **Demonstrating Site-Specific Technologies:** One objective is to showcase technology packages tailored to specific sites on farmers' fields, aiding in adapting to prevailing climate risks.
  - **Capacity Building:** Another goal is to enhance the capabilities of scientists and other stakeholders in conducting climate-resilient agricultural research and applying its findings effectively.
  - **Project Components:** The project comprises four key components: Strategic Research, Technology Demonstration, Capacity Building, and Sponsored/ Competitive Grants.
- **Climate-Smart Villages (CSV):** Strategy to implement and promote climate-smart agriculture at the local level, enhancing farmers' adaptation to climate change.
- **Pradhan Mantri Krishi Sinchayee Yojna (PMSKY):** Scheme prioritizing water conservation and management in agriculture to expand irrigation and improve water use efficiency.
- **Pradhan Mantri Fasal Bima Yojana (PMFBY):** Government-sponsored agriculture insurance program offering financial assistance to farmers in case of crop loss or damage.
- **National Water Mission (NWM):** Launched to ensure Integrated Water Resource Management (IWRM) and increase Water Use Efficiency (WUE), including in agriculture.

Way Forward

- **A recent report from the World Bank, titled "Future of Food:** Crafting a Climate-Resilient Global Food System," emphasized the importance of enhancing climate-smart agriculture. It highlighted the necessity of providing technology access to impoverished farmers, addressing gender disparities, and lowering greenhouse gas emissions by improving fertilizer application, water management, and livestock techniques.
- **Policy Support and Integration:** Governments should formulate and implement policies that promote climate-smart agriculture and integrate it into national agricultural strategies and plans.

- **Knowledge and Capacity Building:** Foster knowledge sharing and capacity building among farmers, extension workers, researchers, and policymakers. Utilize training programs, farmer field schools, demonstration plots, and digital technology to disseminate information and best practices.
- **Research and Development:** Invest in research to deepen understanding of the impact of climate change on agriculture and develop innovative solutions. This includes creating climate-resilient crop varieties, innovative cropping systems, and climate information services to support informed decision-making by farmers.
- Climate-Smart Livestock Production: Promote sustainable livestock management practices to reduce the environmental footprint of livestock production. Focus on improving feed efficiency, enhancing waste management, and utilizing climate-resilient cattle breeds.

IGNITE YOUR MIND

Carbon Footprint Farm Tour: Shrink, Explore, Solve: Shrink down to the size of an ant and embark on a thrilling journey through a farm. Uncover the hidden sources of agricultural emissions from a tiny perspective. Brainstorm ingenious solutions to mitigate these emissions before they reach critical levels.

CONCLUSION

Sustainable development, with its focus on long-term well-being, depends heavily on a healthy and thriving agricultural sector. Sustainable agriculture, nurturing the environment while producing food, forms the cornerstone of a stable and resilient future. By fostering practices that conserve resources, empower communities, and promote biodiversity, we can ensure food security for generations to come, paving the way for a truly sustainable future where human prosperity and environmental health go hand in hand.

Environmental Laws, Organisations and EIA

14

INTRODUCTION

In the pursuit of promoting the sustainable development and safeguarding of the environment, nations worldwide have established a framework of laws, policies and organizations to address environmental concerns within their borders. This chapter delves into the domestic environmental landscape, exploring the legal and policy frameworks, as well as the organizations responsible for ensuring environmental stewardship. Additionally, the chapter examines the crucial practice of Environmental Impact Assessment (EIA) and its role in shaping responsible development.

DOMESTIC ENVIRONMENTAL LAWS

After gaining independence, India faced the challenge of balancing its development needs with its environmental obligations. Several laws and policies were enacted to protect and improve the environment, such as the Wildlife Protection Act, the Air (Prevention and Control of Pollution) Act, the Environment (Protection) Act, the National Green Tribunal Act, and the Water (Prevention and Control of Pollution) Ac,. India also participated in various international conventions and agreements on environmental issues, such as the Stockholm Conference, the Rio Summit, the Paris Agreement and the Kyoto Protocol **(covered in their respective chapters).**

- Originally, the Constitution did not contain any specific provision for Environmental protection.
  - Following the **United Nations Conference on Human Environment in Stockholm in 1972,** the constitution was revised to incorporate the safeguarding of the environment as a constitutional obligation.
- The introduction of the Wildlife Protection Act in 1972 and the 42nd Constitutional Amendment Act in 1976 marked a major shift towards environmental protection in India.
- The 42nd Amendment brought provisions to the Constitution with the introduction of:
  - Article 48A under Directive Principle of State Policy which reads, "The State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country."
  - **Fundamental Duties under Article 51A containing clause (g)** which reads that it is the duty of every citizen to protect and improve the natural environment.
    - It shall be duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures.
- Subsequently, in order to ensure better implementation to environmental protection, the Department of Environment was established in India in 1980 to ensure a healthy environment for the country.
  - This later became the Ministry of Environment and Forests (MoEF) in 1985.

Some of the Laws Passed by India are Listed Below

Wildlife (Protection) Act, 1972

- The enactment of the Wildlife Act of 1972 marks a significant milestone in the nation's wildlife legislation. This is because, at the time, matters pertaining to "Forest" including "Wildlife" were under the jurisdiction of the States as per **Entry 20 of List II of the Seventh Schedule.** Therefore, Parliament lacked authority to legislate on these matters except under the provisions outlined in **Articles 249, 250, and 252** of the Constitution.
- The **Wildlife (Protection) Act of 1972** functions as a legal structure aimed at safeguarding diverse species of wild animals and plants in India.
  - It encompasses the management of their habitats and oversees the trade of wild animals, plants and their derivatives.

Key Provisions

- The act empowers the central and state governments to declare any area of adequate ecological, faunal, floral, geomorphological, natural or zoological significance as a wildlife sanctuary, national park, or closed area.
- The act prohibits hunting of any wild animal except with a permit granted by an authorized officer. The act also specifies the circumstances under which hunting is allowed, such as for self-defense, education, scientific research, or population control.
- The act regulates the trade in wild animals, animal products, and trophies, and prescribes the licenses, fees, and penalties for the same. The act also establishes a Wildlife Crime Control Bureau to combat illegal trade and poaching.

- The Act establishes a National Board for Wildlife, with the Prime Minister as its chair, tasked with advising the central government on issues concerning the conservation and management of wildlife. Additionally, the act outlines provisions for the creation of state wildlife advisory boards, wildlife wardens, and wildlife advisory committees.

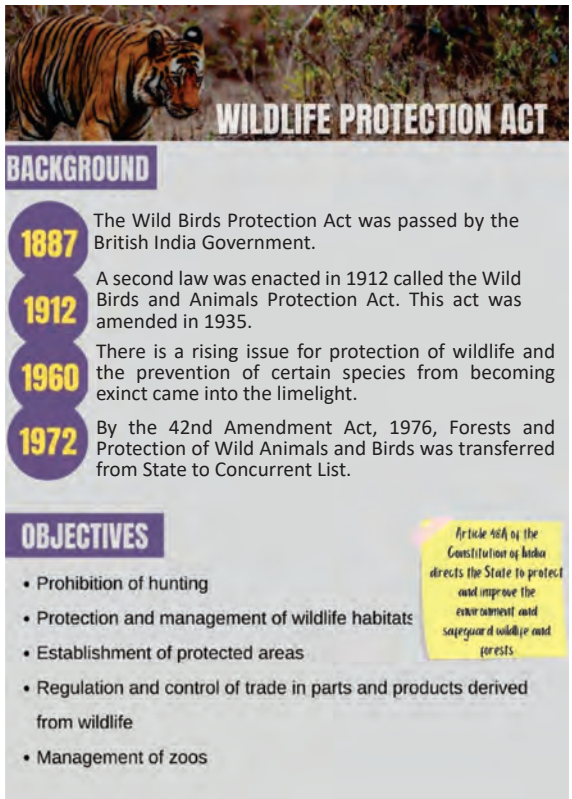

WILDLIFE PROTECTION ACT
BACKGROUND
1887
The Wild Birds Protection Act was passed by the British India Government.
1912
A second law was enacted in 1912 called the Wild Birds and Animals Protection Act. This act was amended in 1935.
1960
There is a rising issue for protection of wildlife and the prevention of certain species from becoming exinct came into the limelight.
1972
By the 42nd Amendment Act, 1976, Forests and Protection of Wild Animals and Birds was transferred from State to Concurrent List.
OBJECTIVES
Article 48A of the Constitution of India directs the State to protect and improve the environment and safeguard wildlife and forests
• Prohibition of hunting
• Protection and management of wildlife habitats
• Establishment of protected areas
• Regulation and control of trade in parts and products derived from wildlife
• Management of zoos

Fig 14.1: Background and Objectives of Wildlife (Protection) Act, 1972

- The act creates six schedules (now 4) which classify the wildlife species according to their degree of protection. The schedules also include the plants that are prohibited from cultivation and planting. The penalties for offences under the act vary depending on the schedule of the wildlife involved.

Schedules under the Act

- **Schedule I:** It provides the highest level of protection to endangered species. Hunting, trade, or possession of any animal was strictly prohibited. Examples: Lion, Tiger, Onehorned rhinoceros, Great Indian Bustard
- **Schedule II:** Animals in this schedule are also given high protection, with hunting and trade generally prohibited. However, exceptions could be made under special circumstances. Examples: Assamese Macaque, Pig Tailed Macaque, Stump Tailed Macaque
- **Schedule III:** Listed species that are not endangered but still need protection. Hunting and trade are regulated, and permits may be required for specific activities. Examples: Chital (spotted deer), Bharal (blue sheep), Hyena, Nilgai
- **Schedule IV:** It includes species that are not considered threatened but are still protected under the WPA. Hunting is generally prohibited, but permits may be issued for specific purposes. Examples: Flamingo, Hares, Falcons, Kingfishers
- **Schedule V:** Listed vermin that can be hunted under specific conditions and with permits from authorized officers. Examples: Rats, Crows, Mice
- **Schedule VI:** Listed plants that are considered endangered or threatened and are protected under the WPA. Up-rooting, damaging, or possessing these plants without permission is prohibited. Examples: Red Sanders, Beddome's Cycad, Pitcher plant

Major Amendments in WLP Act, 1972

- **The Wildlife (Protection) Amendment Act 1982:** This amendment introduced the concept of tiger reserves to protect the endangered tigers and their habitats. It also increased the penalties for wildlife offences and empowered the central government to make rules for the protection of wildlife.
- **The Wildlife (Protection) Amendment Act 1991:** This amendment added more species to the schedules of the act and enhanced the protection of endangered plants. It also prohibited the trade of animal articles and trophies and established the Central Zoo Authority. It also withdrew the State Governments' power to declare vermin species.
  - **Central Zoo Authority (CZA):**
    - It was established in 1992 to regulate and oversee the functioning of zoos in India.
    - It sets up standards for animal housing, healthcare, and breeding programs.
    - It also grants recognition to zoos that meet these standards and provides them with technical guidance.
- **The Wildlife (Protection) Amendment Act 2002:** This amendment established two additional classifications for safeguarded regions: conservation reserves and community reserves. Furthermore, it enhanced the authority of forest officers and heightened the sanctions for wildlife violations. Bodies constituted under the act:
  - **National Board for Wildlife (NBWL):**
    - NBWL serves as the apex body for wildlife conservation in India. It replaced the Indian Board for Wildlife, which was established in 1952 as an advisory board.
    - NBWL is a 47-member committee, chaired by the Prime Minister and includes representatives from various ministries, NGOs, and experts.
    - It advises the central government on matters related to wildlife conservation, protected areas, and sustainable development.

- **State Board for Wildlife (SBWL):**
  - Each state and union territory has its own SBWL, chaired by the Chief Minister or Administrator.
  - Advises the respective state/UT government on wildlife conservation issues within its jurisdiction.
  - Approves projects in and around protected areas.

❑ **Wildlife (Protection) Amendment Act, 2006:**

- **National Tiger Conservation Authority (NTCA):**
  - Created to oversee the implementation of the National Tiger Conservation Programme.
  - Constituted under section 38L (1) of Wildlife (Protection) Act, 1972. The authority consists of:
    - The Minister-in-charge of the Ministry of Environment and Forests (as Chairperson)
    - The Minister of State in the Ministry of Environment and Forests (as Vice-Chairperson)
    - Three members of Parliament
    - Secretary, Ministry of Environment and Forests and other members.
  - The act is responsible for protecting tigers and their habitats across the country.
  - It identifies tiger reserves, develops management plans, and monitors tiger populations.
- **Wildlife Crime Control Bureau:**
  - It was established in 2007 to investigate wildlife crimes across India.
  - Coordinates with various enforcement agencies and gathers intelligence to combat poaching and illegal wildlife trade.
  - Apprehends wildlife criminals and helps prosecute them.
- **Enhanced penalties:** The penalties for various offenses were increased significantly.

** NTCA & WCCB have been covered exhaustively in the biodiversity conservation chapter.

Initiatives for Wildlife Development

❑ The Act has led to the development of various species conservation programs for endangered and threatened species, such as:
- Project Tiger Conservation (1973), Project Elephant (1992), Wildlife Corridors etc.

❑ The legislation grants the government the authority to designate a range of protected zones, such as National Parks, Wildlife Sanctuaries, Conservation Reserves, and Community Reserves.

Authorities Appointed under the Act

❑ The Director of Wildlife Preservation, along with assistant directors and other staff accountable to them, is appointed by the central government.

❑ At the state level, a Chief Wildlife Warden is appointed by the state government to supervise the wildlife department and administer protected areas within the state.

❑ Additionally, Wildlife Wardens are appointed by state governments in each district to assist in wildlife protection initiatives.

The Vermin Conflict

❑ **Vermin Identification under WLPA (1972):**
- Since 1972, the Wildlife Protection Act (WLPA) has categorized fruit bats, common crows and rats as vermin.
- The permission to kill animals beyond this specified list was granted under certain conditions.

❑ **Vermin Declaration Criteria:**
- Section 62 of WLPA permits the declaration of any species, excluding highly protected ones, as vermin in a specific place and for a defined duration with valid reasons.
- Section 11 of WLPA allows state wildlife wardens to authorize killing if an animal, irrespective of its status, poses a threat to human life.

❑ **Shift in Decision-Making Authority (1991):**
- Until 1991, state governments made vermin-related decisions under Section 62.
- An amendment transferred this authority to the Centre, intending to restrict mass eliminations at a species level.

❑ **Recent Misuse of Section 62 Powers:**
- The Center is currently employing Section 62 authorities to designate species as pests at the state level without reliable scientific evaluations.
- Examples include nilgais in Bihar (2015) and monkeys in Shimla municipality (2019), citing agricultural destruction as grounds.

❑ **Political Dimension and Center-State Debate:**
- Center-state politics are now entangled in the vermin declaration issue.
- Kerala's repeated requests to declare wild boars as vermin have been denied, leading to a divided House debate.

❑ **Divergent Perspectives in the Debate:**
- Members from Kerala highlight the increasing wild boar attacks, advocating for vermin status.
- Others propose a more measured and scientifically grounded approach to declaring a species as vermin.

Wildlife Protection Amendment Act, 2022

The Wildlife Protection Amendment Act 2022 is a bill that aims to amend the Wildlife Protection Act 1972, which regulates the protection of wild animals, plants and their habitats in India. Some of the main features of the bill are:

❑ It adds a new schedule for the species outlined in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a global agreement designed to thwart the extinction of wild animals and plants caused by trade.

- This gives authority to the Central government to designate a Management Authority and a Scientific Authority, responsible for issuing permits and offering counsel on issues pertaining to the trade of wildlife specimens.
- Additionally, it grants the Central government the authority to control or forbid the import, trade, or possession of invasive alien species—species not native to a particular region that can pose harm to indigenous wildlife or their environments.
- It enhances the penalties for violating the provisions of the act, such as increasing the maximum fine from Rs 25,000 to Rs 1 lakh for general violations and from Rs 10,000 to Rs 25,000 for offences involving specially protected animals.
- It permits the use of elephants for religious or any other purposes, which has been criticized by some wildlife activists as a potential loophole for commercial trade of elephants.
- It allows for specific authorized activities within designated areas, including grazing, the movement of livestock, and the utilization of drinking and household water by local communities.

New Schedules under the Act: Previously, there were 6 schedules under the act, but The Wildlife (Protection) Amendment Act, 2022 reduced the number of schedules from six to four.

Schedules	Description	Examples
Schedules I	Contains animal species enjoying the highest level of protection. Hunting, trade, and collection of these species are strictly prohibited	Tigers, lions, elephants, one-horned rhinos, Great Indian Bustards
Schedules II	Includes animal species subject to a lesser degree of protection compared to Schedule I. Hunting and trade are generally prohibited, but exceptions may be allowed in specific cases	Blackbucks, leopards, sloth bears, pangolins
Schedules III	List protected plant species. Trade and collection of these plants are regulated.	Sandalwood, red sanders, medicinal plants
Schedules IV	Includes scheduled specimens listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Trade and Possession of these species are regulated based on their listing in CITES appendices.	Species listed under CITES

No person shall hunt any wild animal specified in Schedules I, II, III and IV except for certain conditions:

- The Chief Wildlife Warden can allow the hunting of an endangered wild animal if they decide it poses a threat to humans or is severely injured or ill with no chance of recovery. The Warden must give a written explanation for their decision.
- The Chief Wildlife Warden or an authorized officer can issue a written permit to hunt wild animals (from Schedules II, III, or IV) if those animals pose a threat to humans, property, or crops.
  - Such animal or group of animals in a specified area or cause such animal or group of animals in that specified area to be hunted
- Causing harm or injury to any wild animal in a sincere effort to defend oneself or another person is not considered a criminal offense.
- The Chief Wild Life Warden may issue a permit, through a written order providing the reasons, to any individual upon payment of the prescribed fee. This permit allows the holder to hunt, under specified conditions, any wild animal mentioned in the permit. The hunting is permissible for purposes of education and scientific research.

Species under Various Schedules

Schedule I:

Pangolin, Pygmy Hog, Rhinoceros, Serow, Malabar Civet, Lesser or Red Panda, Lion-Tailed macaque, Indian Elephant, Indian lion, Indian wild Ass, Indian wolf, Kashmir Stag, Himalayan Tahr, Giant squirrel, Cheetah, Chinese Pangolin, Blackbuck, Himalayan Brown bear, Sloth Bear, Slow Loris, Snow Leopard, Swamp Deer, Tiger, Gharial, Ganges Soft-shelled Turtle, LoggerHead Turtle, Olive Back Loggerhead Turtle, Peacock-marked Soft-shelled Turtle, Pythons, Sail terrapin, Spotted black Terrapin, Black-necked crane, Great Indian Bustard, Great Indian Hornbill, Pink-headed duck, Vultures, Sperm Whale

Schedule II:

Nilgai, Indian Flying Fox, Spotted Deer/Chital, Indian Hedgehog, Wild Pig, Sri Lanka Bay Owl, Chinese Egret, Chinese Pond Heron, Common Raven, Asian Koel, Common Cuckoo, Greater Flamingo, Lesser Flamingo, Indian Grey Hornbill

Schedule III:

Neel kurinji, Gold threat, Mishmi teeta, Tree turmeric, Common yew, Blue vanda, Pitcher plant, Red vanda, Daffodil orchid, Indian podohyllum

Schedule IV:

Antelopes, cattle, duikers, gazelles, goats, sheep, Camels, Deer, Dogs, foxes, wolves

Concerns

- Despite the strict penalties and enforcement measures, many wild animals and plants are still hunted and traded for various purposes. Some of the most targeted species include tigers, rhinos, elephants, pangolins, and red sanders.
- CITES is an international treaty that regulates the trade of endangered species of wild fauna and flora. India is a signatory to CITES, but the act does not cover all the obligations and provisions of the treaty, such as the requirement of permits, certificates, and labels for the export and import of wildlife specimens.
- The act does not adequately address the conservation of freshwater fish species, which are facing severe threats. Freshwater fish are important for ecosystem services, but many of them are endangered or critically endangered, such as the golden mahseer, and humpback mahseer.
- India is home to a large number of migratory birds, which travel across continents and countries every year. However, the act does not have specific provisions for the conservation and management of these birds, which are facing multiple challenges. Some of the migratory birds that have shown a decline in their population include the Amur falcon, bar-headed goose, and Siberian crane.

Way Forward

- Enhance enforcement against wildlife poaching and illegal trade by boosting manpower, training, and equipment for officials.
- Improve coordination among forest officials, wildlife crime bureaus, and customs authorities.
- Harmonize wildlife protection acts with CITES obligations, including issuing permits and ensuring compliance with appendices and resolutions.
- Developing and implementing specific provisions and plans for the conservation and management of migratory birds. This could involve enhancing the scientific monitoring and assessment of their population and distribution, establishing and maintaining their flyways and stopover sites, and promoting regional and international cooperation and agreements.

The Wildlife Protection Act of 1972 has played a critical role in conserving India's rich wildlife heritage. However, ongoing challenges require continued efforts to ensure the effective implementation of the Act and the long-term survival of India's wildlife.

Environment Protection Act (EPA) 1986

The Environment Protection Act (EPA) 1986 is an important law that seeks to safeguard and enhance environmental quality while preventing, managing and mitigating pollution. The Act grants authority to the Central Government to implement essential measures for environmental protection and to synchronize the efforts of diverse authorities established by other environmental laws. It also empowers central government to lay down the standards for emission or discharge of environmental pollutants from various sources

- The EPA Act was established pursuant to Article 253 of the Indian Constitution, which authorizes the formulation of laws to implement international agreements.
- The last amendment to the Act happened in 1991.

Background

The Environment (Protection) Act, 1986 (EPA 1986) emerged from a confluence of factors:

- **International impetus:**
  - **The United Nations Conference on the Human Environment (Stockholm, 1972):** This global event raised awareness about environmental issues and led to the adoption of the Stockholm Declaration, outlining principles for environmental protection. India, as a participant, committed to taking steps towards this goal.
- **Domestic developments:**
  - **Growing environmental concerns:** Throughout the 1970s and 1980s, India witnessed growing public concern about environmental degradation, including issues like air and water pollution, industrial waste disposal, and deforestation.
  - **The Bhopal Gas Tragedy (1984):** This industrial disaster, considered as one of the worst environmental catastrophes, served as a stark wake-up call, highlighting the need for stricter environmental regulations and enforcement.

Objectives

- To safeguard and enhance the environment
- To mitigate and manage environmental pollution
- To promote community engagement in the protection of the environment

Key Provisions of the Act

- The Act addresses various types of pollution, including air, water, soil, and noise. It establishes safe benchmarks for the acceptable levels of different pollutants in the environment and restricts the utilization of hazardous substances without obtaining prior approval from the Central Government.
- The Act grants the Central government the authority to implement any measures it considers essential for environmental protection. According to the statute, it is authorized to organize and implement nationwide initiatives and strategies to advance environmental protection.
- The Act also gives the Centre the power to issue directions to any person, officer or authority, and such person, officer or authority shall be bound to comply with such directions. This includes the power to stop, regulate or prohibit any activity that is likely to cause environmental pollution or harm.

- The Act also provides for the appointment of officers and their powers and functions to carry out the provisions of the Act. These officers have the authority to enter, inspect, collect samples, examine records and issue notices to any person who is suspected of violating the Act or the rules made under it.
- The Act also imposes penalties for violating its provisions or rules, orders and directions issued under it. For each failure, a fine of up to 1 Lakh, a prison term of five years, or both can be included. In certain cases, the term can be extended up to seven years.
- The Act also encourages public participation in the protection of the environment by providing for the disclosure of information, public complaints and Environmental Impact Assessment.

- The Central Ground Water Authority (CGWA), established under Section 3(3) of the Environment (Protection) Act, 1986, is responsible for overseeing and managing the development of groundwater resources nationwide. It issues regulatory directives as needed and holds authority for appointing officers under the Act.
  - **Powers:**
    - **Environmental Protection:** The CGWA draws its power from the Environment (Protection) Act, 1986, specifically focusing on areas outlined in Section 3(2). This allows them to issue instructions and enforce compliance to ensure environmental protection.
    - **Legal Enforcement:** The CGWA has the authority to leverage the legal framework outlined in Sections 15 to 21 of the aforementioned Act. This empowers them to take legal action against violators of their directives.
    - **Sustainable Groundwater Management:** The CGWA plays a crucial role in managing groundwater resources responsibly and sustainably. This includes overseeing well construction, registering groundwater extraction structures, and regulating the commercial sale of groundwater.

Important Notifications Issued under EPA 1986

- The Coastal Regulation Zone Notification (1991) regulates activities along coastal areas. In December 2018, the Union cabinet approved the Coastal Regulation Zone (CRZ) Notification, 2018, which aim at promoting sustainable development and the conservation of coastal resources.
- The Environmental Impact Assessment of Development Projects Notification (1994), which requires prior environmental clearance for certain categories of projects that may cause significant environmental degradation. The notification was amended in 2006 and 2020 to streamline the process and address the concerns of various stakeholders.
- The Ozone Depleting Substances (Regulation and Control) Rules (2000), which prohibit the import, export, manufacture, use, sale, or storage of ozone depleting substances and products containing them, in accordance with the Montreal Protocol on Substances that Deplete the Ozone Layer.
- The Bio-Medical Waste Management Rules (2016), which provide for the safe and scientific management of bio-medical waste generated from health care facilities, research institutions, and veterinary establishments.
- The Plastic Waste Management Rules (2016), which aim to reduce the generation and use of plastic waste and ensure its proper collection, segregation, recycling, and disposal.
- The Solid Waste Management Rules (2016), which are applicable to various entities, including urban local bodies, urban agglomerations, census towns, industrial townships, areas controlled by Indian Railways, airports, airbases, ports and harbors, defense establishments, special economic zones, state and central government organizations, as well as places of pilgrimage, religious significance, and historical importance.

Challenges

- **Centralized Power:** It raises concerns about arbitrariness and limited local responsiveness.
- **Insufficient public involvement:** It leads to lack of transparency and ignores valuable local knowledge.
- **Incomplete coverage:** It does not address emerging pollutants or adapt to technological advancements.
- **Omitted forest protection:** Creates gaps in comprehensive environmental protection strategies.
- **Proposed decriminalization:** The MoEFCC's proposal to amend the act to remove the imprisonment as a penalty for the "less severe" contraventions may dilute the effectiveness and seriousness of the EPA and encourage more violations of the environmental norms

Way Forward

- **Decentralization & Collaboration:** We can learn from the EU's framework approach and Brazil's multi-level governance for better responsiveness and diverse perspectives.
- **Public Participation:** Implement mandatory hearings and awareness campaigns, inspired by the US's NEPA and the Aarhus Convention's public participation principles.
- **Emerging Challenges:** Adapt approaches like the Stockholm Convention's POPs regulation and the Montreal Protocol's ozone protection to address new environmental threats.

- **Forest Protection:** Draw inspiration from REDD+ and the Bonn Challenge to integrate forest protection measures into the Act and foster collaboration with forestry departments.

The EPA 1986 demonstrates India's commitment to environmental protection, reflecting both global awareness and domestic concerns. The Act provides a comprehensive framework for addressing various forms of pollution and ensuring sustainable development.

Water (Prevention and Control of Pollution) Act, 1974

The Water (Prevention and Control of Pollution) Act, 1974 is a significant legislation designed to prevent and manage water pollution while preserving or restoring water quality. This law **establishes the Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs).** These boards have the power and function to monitor, regulate, and enforce the provisions of the Act and the standards set by the government. The Act also defines what constitutes water pollution and prescribes penalties for violating its provisions.

Key Features

- **Establishment of Central and State Pollution Control Boards (CPCB and SPCBs):** The Act establishes a two-tiered system for water pollution control. The CPCB acts as the central coordinating agency, while SPCBs are responsible for implementing the Act in their respective states.
- **Regulation of polluting industries:** The Act requires industries to obtain consent to discharge effluents from the SPCBs. These consents specify the quality and quantity of pollutants that can be discharged.
- **Prohibition on polluting water bodies:** The Act prohibits the discharge of untreated sewage and industrial effluents directly into water bodies.
- **Power to inspect and take samples:** The Act empowers authorized officials to inspect industrial premises and take samples of effluents for analysis.
- **Penalties for violations:** The Act prescribes penalties for violating its provisions, including imprisonment and fines.

The Water (Prevention and Control of Pollution) Act, 1974, plays a crucial role in the regulatory framework for environmental protection in India. It focuses specifically on water pollution, providing mechanisms for monitoring, control, and enforcement to safeguard water resources and ensure their sustainable use.

IGNITE YOUR MIND

H2O Heroes: Guardians of the Lifeblood: As water scarcity looms large, what laws like the Water Act act as shields protecting this precious resource? Dive deep into the intricacies of water pollution control legislation and explore its impact on ensuring clean water for all.

Air (Prevention and Control of Pollution Act) 1981

The Air (Prevention and Control of Pollution) Act, 1981, often referred to as the Air Act for brevity, is a landmark piece of legislation enacted by the Indian Parliament in 1981. It represents the country's first major step towards tackling air pollution, a significant problem in India.

Purpose

- Preventing, managing and mitigating air pollution.
- Establishing central and state-level boards to supervise these initiatives.
- Specifying the powers and responsibilities of these boards in relation to controlling air pollution.

Key Provisions

- It defines "air pollutant" as any solid, liquid, or gaseous substance that can harm human health, the environment, plants, animals, or property. This definition was expanded in 1987 to include noise.
- It empowers the central government to:
  - Set emission standards for various industries and automobiles.
  - Declare "air pollution control areas" where stricter regulations apply.
  - Make rules for implementing the Act.
- It empowers state governments to:
  - Establish state pollution control boards.
  - Implement the provisions of the Act within their jurisdiction.
  - Make rules for specific situations within their state.
- The Central Pollution Control Board (CPCB)/ State Pollution Control Board (SPCB) has been granted authority to serve as the primary agency responsible for regulating air pollution in India. **Note:** These bodies are constituted under the Water Act 1974.
- Requires industries not to exceed the emission standards set by the state board.
- Provides for inspections, penalties, and closure of industries violating the Act.

Significance

The Air Act has played a crucial role in raising awareness about air pollution and prompting various measures to address it. However, ongoing challenges like rapid industrialization, vehicle emissions, and agricultural practices contribute to persistent air pollution concerns in India.

Offences and Penalties: The Act prescribes various offences and penalties for violations of its provisions.

Major Offences

- **Non-compliance with emission standards:** This is a major offence punishable under the Act.The consequences include imprisonment for a period not less than one year and six months, up to a maximum of six years, in addition to a monetary fine. Moreover, if the offence persists, a continuing violation incurs an additional daily fine of ₹5,000.

- **Failure to comply with Board's directions:** Failure to adhere to the specific instructions given by the Pollution Control Board may result in imprisonment for a period of up to one year, a fine of up to ₹10,000, or both. In instances of non-compliance, the fine may be increased to ₹5,000 per day.
- **Establishing or operating industries without consent:** Operating an industry without obtaining the necessary consent from the Board is an offence punishable with imprisonment for up to three months or a fine of up to ₹10,000, or both.
- **Tampering with monitoring devices:** Tampering with or damaging any air monitoring equipment installed by the Board is an offence punishable with imprisonment for up to one year or a fine of up to ₹10,000, or both.

Penalties for Companies and Government Departments

- If a company commits an offense, the individual overseeing the company's business at the time of the offense is also accountable for punishment, in addition to the company.
- Government departments are also liable for penalties if they violate the Act.

Additional Points

- **Cognizance of offences:** Offences under the Air Act are cognizable, meaning the police can arrest offenders without a warrant in certain cases.
- **Protection:** The Act provides protection for individuals acting in good faith.
- **Power to close down industries:** The SPCB has the power to close down industrial plants that are causing significant air pollution or are not complying with the provisions of the Act.

The Air (Prevention and Control of Pollution) Act, 1981, along with other environmental legislations, forms a critical component of India's regulatory framework for environmental protection and sustainable development. It addresses the specific challenges associated with air pollution and provides mechanisms for monitoring, control, and enforcement.

IGNITE YOUR MIND

Airpocalypse Busters: Code Red for Smog: As air pollution chokes our cities, what are the legal weapons in our arsenal to combat this invisible enemy? Crack the code of the Air (Prevention and Control of Pollution) Act and analyze its effectiveness in clearing the air.

The Indian Forest Act, 1927

The Indian Forest Act, 1927, is a significant piece of legislation governing forests and their management in India.

Main Objectives

- To consolidate and regulate laws related to forests, forest produce, and timber duties.
- To declare and manage different types of forests:
  - **Reserved Forests:** Highly protected, with stringent regulations on access and activities.
  - **Protected Forests:** Less strictly controlled, but specific activities require permission.
  - **Village Forests:** Managed by local communities for their needs.
- To control the movement and trade of forest produce.
- To prevent deforestation and promote sustainable forest management.

Key Provisions

- It defines the procedure to be followed in relation to the declaration, settlement, and management of the different types of forests. It also specifies the powers and duties of the forest officers and the state government in this regard.
- It imposes a duty on timber and other forest produce that is extracted from the forests or transported within or outside the state. The duty is levied by the state government and varies according to the type and quantity of the forest produce.
- It regulates the transit of timber and other forest produce by requiring a permit or a certificate from the forest officer or the state government. It also provides for the establishment of check posts, depots, and stations for the inspection and verification of the forest produce in transit.
- It deals with the collection of drift and stranded timber, which are the timber and other forest produce that are found floating or lying on the banks of any river, lake, or watercourse. It gives the right of ownership of such timber to the state government, unless it is claimed by the rightful owner within a specified period.
- It defines the offences and penalties pertaining to the forests, such as trespassing, encroachment, cutting, burning, grazing, hunting, fishing, etc. It also prescribes the procedure for the arrest, search, seizure, and trial of the offenders. It also provides for the compensation and restoration of the damage caused to the forests.
- It empowers the State Government to appoint forest officers with specific powers to manage forests, investigate offences, and enforce the provisions of the Act.
- It allows the establishment of Forest Advisory Boards at both central and state levels, offering guidance to the government on issues related to forests.

The Indian Forest Act, 1927 has been criticized for its focus on conservation over the rights of local communities. However, it remains an important law that plays a key role in the management of India's forests.

Forest (Conservation) Act, 1980

The Forest (Conservation) Act, 1980 (FCA) was enacted to ensure the conservation of forests and regulate the use of forest land for non-forest purposes. It was enacted in response to growing concerns about deforestation in India.

Objectives of the Act

- To check further deforestation in the country.
- To conserve the existing forest cover.
- To increase forest cover through afforestation and reforestation.
- To protect the rights and interests of forest-dwelling communities.

Key Provisions

- **Restriction on Dereservation:** It prohibits the dereservation of forests, meaning converting reserved forest land for non-forest purposes like agriculture, mining, or infrastructure development.
- **Prior central Government Approval:** The act makes it mandatory to obtain prior approval from the Central Government before using any forest land for non-forest purposes.
- **Compensatory Afforestation:** In accordance with the Forest (Conservation) Act of 1980, whenever there is a diversion of forest land for non-forestry purposes, an equivalent area of non-forest land (revenue land) or double the area of degraded forest land must be reforested as compensatory afforestation (CA).
- **Advisory Committee:** The Act provides for the constitution of a Central Advisory Committee to advise the central government on matters relating to the conservation of forests.
- **Power to Make Rules:** It empowered the Central Government to set forth regulations ensuring the efficient enforcement of the provisions within the Act.

Forest Advisory Committee

- Established by the **Forest (Conservation) Act 1980,** this statutory body operates under the Ministry of Environment, Forests & Climate Change (MoEF&CC).
- FAC's primary role is to evaluate proposals for diverting forest land (over five hectares) for non-forest purposes like mining, industrial projects, and townships.
- The Central government, through FAC, **approves or rejects requests for diverting land,** ensuring a thorough examination of the user agency's case and its environmental impact mitigation plan.
- Once FAC approves or rejects a proposal, it goes to the concerned State government, which must comply with the Forest Right Act, 2006, protecting the rights of forest dwellers and tribals.
- FAC approval **necessitates compensatory land provision for afforestation** and payment of net present value by future users (ranging between ₹10-15 lakh per hectare).

The Forest (Conservation) Amendment Bill 2023

The bill amends the Forest (Conservation) Act of 1980 to extend its applicability to specific categories of land. This encompasses land officially designated as a forest under the Indian Forest Act of 1927 or documented as such in government records following the enactment of the 1980 Act.

Background

- Post Independence, extensive portions of forested areas were demarcated as reserved and protected forests. Nonetheless, numerous forested regions were excluded, and lands devoid of standing forests were classified as 'forest' lands.
- In the 1996 Godavarman case, the Supreme Court halted nationwide tree felling and decreed that the Forest Conservation Act (FC Act) would be applicable to all land parcels identified as 'forest' or resembling the dictionary definition of a forest.
- In June 2022, the government modified the Forest Conservation Rules to propose a mechanism permitting developers to establish plantations "over land not covered by the (FC) Act" and exchange such plots for future compensatory afforestation requirements.

Key Features

- **Land under the purview of the Act:**
  - Forest land declared/notified under the Indian Forest Act, 1927, or any other law.
  - Land notified as a forest on or after October 25, 1980, in a government record.
  - Excludes land changed from forest use to non-forest use before December 12, 1996, by authorized state/UT authorities.
- **Exempted categories of land:**
  - Exempts specific types of forest land, such as those along rail lines or public roads, roadside amenities (up to 0.10 hectare).
  - Exempts forest land within 100 km from international borders, Line of Control, or Line of Actual Control for strategic projects.
  - Exempts land (up to 10 hectares) for security-related infrastructure or defense projects.
  - Exempts land proposed for defense projects, paramilitary camps, or public utility projects (up to five hectares) in left-wing extremism affected areas.

- **Assignment/leasing of forest land:**
  - Requires prior approval from the central government for state governments to assign forest land to any entity (including government-owned and controlled entities).
    - The central government sets specific conditions that must be met for approval.
- **Permitted activities in forest land:**
  - Forest land de-reservation or non-forest use is prohibited without prior approval from the central government.
  - Recognizes particular exempted actions intended for non-forest purposes, including conservation, administration, and development endeavors.
  - The Bill adds activities like zoos, safaris, ecotourism facilities, silvicultural operations, and others to the list.
  - The central government has the authority to define terms and conditions in order to designate certain surveys as not falling under the category of non-forest purposes.
- **Power to issue directions:**
  - Authorizes the central government to provide directives for the execution of the Act to any authority or organization affiliated with or acknowledged by the central, state or union territory.

Challenges

- Centralization of power in the Forest Clearance Act has led to bureaucratic delays, corruption, and accountability issues, as authority shifted from states to the central government.
- The Act overlooks the rights of local communities, particularly tribal and forest-dwelling people, who rely on forests for their livelihood and cultural practices.
- The Act fails to address root causes of deforestation like population pressure, poverty, landlessness, and unsustainable development, neglecting ecological and social aspects of conservation.
- Emphasis on quantity over quality of forest cover results in insufficient focus on regeneration and restoration of degraded forests.
- Misinterpretation and misuse of the Act by various stakeholders, including the forest department, industry, judiciary, and civil society, has led to justifying encroachment and exploitation of forest land.
- Legal conflicts and uncertainties arise from challenges to the Act by environmental activists and affected communities in the courts.

Way Forward

- Decentralize and democratize forest governance through involvement of state governments, local bodies and community institutions.
- Recognize and respect customary and statutory rights of forest-dependent people, ensuring their participation and benefit-sharing in conservation.
- Address socio-economic and environmental drivers of deforestation with a holistic approach.
- Promote sustainable livelihoods for forest-dependent people through agroforestry, eco-tourism, and non-timber forest products.
- Incorporate ecosystem-based management, landscape restoration, and climate resilience in forest conservation strategies.
- Strengthen and streamline forest clearance process for transparency, accountability, and public participation.
- Establish clear criteria and guidelines for forest land diversion, ensuring compliance and enforcement.

The Forest (Conservation) Act, 1980, plays a crucial role in balancing the needs of development with the imperative of forest conservation. It reflects the recognition of the ecological importance of forests and the need to ensure sustainable development practices to protect the environment and biodiversity.

National Forest Policy, 1988

The National Forest Policy, 1988 is a policy document that guides the management of forests in India. It was enacted by the Government of India to revise the previous National Forest Policy of 1952. The main aim of the policy is to ensure environmental stability and ecological balance through conservation and sustainable use of forests. Some of the objectives of the policy are:

- To maintain and increase the forest and tree cover in the country, especially on degraded and unproductive lands.
  - The policy recommends that 33% of the total land area of the country should be under forest or tree cover. The policy also recommends 33% forest cover for the plains and 67% for the hills.
- To meet the needs of fuel-wood, fodder, minor forest produce and small timber of the rural and tribal populations.
- To conserve the natural heritage and biodiversity of the country, including the flora and fauna.
- To check soil erosion, desertification, floods, droughts and siltation of reservoirs.
- To encourage efficient utilisation and substitution of forest products.
- To create a people's movement with the involvement of women for achieving these objectives.

New Draft National Forest Policy, 2018

The Draft National Forest Policy (NFP) of 2018 aims to conserve, protect and manage forests. The policy's main objectives are:

- Aim to afforest or plant trees across a minimum of one-third of India's total land area.
- Tackle the decrease in forest productivity effectively.

- Utilize degraded land owned by forest corporations to generate high-quality timber.
- Implement sustainable practices for managing edibles, fibers, bamboo and grass to enhance the income of tribal communities and other populations dependent on forests.
- Counter threats to forests arising from encroachments, illegal tree cutting, forest fires, invasive weeds, grazing, etc.
- Integrate climate change mitigation and adaptation through the implementation of REDD+ (reducing emissions from deforestation and forest degradation in developing countries).
- Adopt green accounting measures.
- Effectively manage green spaces within urban environments.
- Establish a robust monitoring and evaluation framework to ensure credibility and effectiveness.

IGNITE YOUR MIND

Policy Puzzles: The Bigger Picture: Environmental policies are like intricate jigsaw puzzles, with various pieces working together. How do different policies, like the National Forest Policy, fit together to achieve broader environmental goals?

Forest Rights Act (FRA), 2006

The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, also known as the Forest Rights Act (FRA), is a landmark legislation that recognizes the rights of forest dwelling Scheduled Tribes and Other Traditional Forest Dwellers (OTFDs) to forest land and resources.

- The Act applies to forest dwelling communities residing in forests before December 13, 2005.
- It emphasizes the role of Gram Sabhas in decision-making processes related to forest rights.
- The implementation of the Forest Rights Act (FRA) 2006 falls under the purview of the Ministry of Tribal Affairs (MoTA), which serves as the primary agency for this purpose.

Key Features of the FRA

- **Recognition of rights:** The legislation acknowledges diverse forest rights, encompassing:
  - **Title rights:** FDST and OTFD are granted ownership rights to land cultivated by tribal or forest-dwelling communities, with a maximum limit of 4 hectares.
    - Ownership is restricted to land actively cultivated by the respective family, and no additional land grants will be provided.
  - **Usage rights:** The rights of the dwellers extend to extracting Minor Forest Produce, grazing areas, to pastoralist routes, etc.
  - **Relief and development rights:** To rehabilitation in case of illegal eviction or forced displacement and to basic amenities, subject to restrictions for forest protection
  - **Forest management rights:** It includes the right to protect, regenerate or conserve or manage any community forest resource which they have been traditionally protecting and conserving for sustainable use.
  - The rights under the FRA are individual for homestead and cultivation, and can only be inherited, not transferred.
  - Forest rights can be asserted by individuals or communities that have been residing in forest land for genuine livelihood requirements for a minimum of three generations (75 years) before December 13, 2005.
- **Community forest resource rights:** The Act provides for the formation of Gram Sabhas (village councils) to manage and protect community forests. It empowers communities to develop and implement forest management plans and share benefits from the use of forest resources.
- **Protection from displacement:** The Act prohibits the eviction of forest dwellers from their land without their consent and provides for their rehabilitation in case of displacement for development projects.
- **Institutional framework:** The Act establishes a three-tiered system for the implementation of its provisions, with Gram Sabhas at the village level, Sub-Divisional Level Committees at the sub-divisional level, and District Level Committees at the district level.
- **Forest Rights Committees (FRCs):** It sets up FRCs at the district level to provide guidance on the Act's implementation and address grievances associated with forest rights.

- **Critical Wildlife Habitat:** It refers to areas within protected areas (such as wildlife sanctuaries, national parks, and tiger reserves) where the rights of forest dwellers may be modified or resettled for the purpose of wildlife conservation. They are recognised under the FRA.
  - CWHs are different from core or critical tiger habitats, which are defined in the Wildlife (Protection) Act, 1972.
  - CWHs are supposed to be identified and notified by the state governments based on scientific and objective criteria, in consultation with an expert committee and the affected communities.
    - The Chief Wildlife Warden of a state must notify an Expert Committee for the identification of CWHs in a national park or sanctuary.

Minor Forest Produce (MFP) and Tribal Rights in India

Minor Forest Produce (MFP) is a subset of forest produce and got a definition only in 2007, when the Forest Rights Act, 2006 was enacted. The Act defines a Minor Forest Produce (MFP) as all non-timber forest produce of plant origin. This includes: Bamboo, Leaves (Tendu, Sal, etc.), Fruits, Seeds, Flowers (Mahua), Honey, Lac, Medicinal Plants, Resins & Gums, etc.

- **Significance for Tribal Communities**
  - **Source of Livelihood:** MFPs often form the backbone of the tribal economy, providing both sustenance and income through the collection and sale of these products.
  - **Food Security:** Many MFPs are directly consumed by tribal communities, ensuring food security and nutrition.
  - **Traditional Medicine:** Tribal communities have extensive knowledge about the medicinal properties of various MFPs, using them for traditional healing practices.
  - **Cultural Importance:** Certain MFPs hold deep spiritual and cultural significance within tribal societies.
- The Forest Rights Act (2006) and MFP: The Forest Rights Act recognizes the following rights of forest-dwelling communities over MFPs:
  - **Ownership Rights:** The right to own, use, and sell MFPs traditionally collected within or outside village boundaries.
  - **Access Rights:** The right to access, collect, and use MFPs for self-consumption or sale.
  - **Protection Rights:** The right to protect, regenerate, and manage community forest resources, which include areas where MFPs are found.

Habitat Rights under FRA, 2006

- Habitat rights are given to PVTGs under **section 3 of the Forest Rights Act, 2006.** This encompasses the entitlements to habitat and habitation community tenures for primitive tribal groups and pre-agricultural communities.
- These rights play a pivotal role in preserving and promoting traditional livelihoods and ecological knowledge that are passed down through generations.
- Additionally, they facilitate the convergence of diverse government schemes and initiatives from different departments, empowering Particularly Vulnerable Tribal Groups (PVTGs) to enhance and develop their habitats.
- **As defined by the Forest Rights Act (FRA), "habitat" includes customary living spaces in addition to those in reserved and protected forests for PVTGs and other forest-dwelling Scheduled Tribes.**
- Among the 75 PVTGs in India, only three currently hold habitat rights.
  - The **Bharia** PVTG in Madhya Pradesh was the pioneer, followed by the **Kamar** tribe, and most recently, the Baiga tribe in Chhattisgarh.
- The declaration process for habitat rights, established by the **Ministry of Tribal Affairs,** involves consulting traditional tribal leaders to assess the cultural, traditional, and occupational aspects.

Challenges

- **Balancing Individual Rights and Community Rights:** In certain states, politicians have predominantly emphasized individual rights, essentially transforming the Act into a scheme focused on 'encroachment regularization.' Unfortunately, this approach overlooks the importance of acknowledging and safeguarding community rights, which play a crucial role in ensuring sustainable forest management.
- **Insufficient Recognition of Individual Forest Rights (IFRs):** Acknowledging Individual Forest Rights has been inadequate, often hindered by opposition from the Forest Department, apathy from other government bodies, and the misuse of technology.
  - Those seeking recognition face obstacles in the filing process, encountering flawed and non-transparent rejections, along with arbitrary partial acknowledgments.
- **Challenges of Digital Processes in Areas with Limited Connectivity:** The introduction of digital processes, as seen with the VanMitra software in Madhya Pradesh, poses challenges in regions with poor connectivity and low literacy rates.
  - This worsens existing inequalities and hinders the smooth submission and processing of claims.
- **Incomplete Acknowledgment of Community Forest Rights (CFRs):** The slow and incomplete recognition of community rights to access and manage forests (CFRs) represents a significant gap in the implementation of the Forest Rights Act (FRA).
  - The resistance from the forest bureaucracy to these rights could hinder the empowerment of local communities in forest management.
- **Limited Recognition of CFRs in Most States:** While Maharashtra, Odisha, and Chhattisgarh have made progress in recognizing CFRs, this advancement is not reflected in most states.
  - Maharashtra's positive example of activating CFRs through the de-nationalization of minor forest produce is overshadowed by persistent challenges, particularly in areas vulnerable to mining.

Way Forward

- **Strengthening Gram Sabha:** Actively involve the local self-government, Gram Sabha, in decision-making processes regarding forest management to enhance their empowerment.
- **Fostering Inclusive Decision-Making:** Ensure the participation of rights holders in decision-making processes, incorporating their perspectives to effectively address their needs.
- **Educational Outreach and Training:** Organize awareness programs and training sessions for forest dwellers, enlightening them about their rights outlined in the Forest Rights Act (FRA).
- **Capacity Building:** Enhance the capabilities of civil society organizations to advocate for and support the rights of forest dwellers.
- **Implementing Monitoring Systems:** Establish mechanisms for monitoring to ensure compliance with the provisions and objectives of the Forest Rights Act (FRA) by the Forest Department and other relevant authorities.
- **Holistic Planning:** Formulate integrated plans considering both developmental and conservation aspects of forests, respecting the rights and interests of forest dwellers.

The Forest Rights Act, with its comprehensive rights framework and focus on community involvement, represents a significant step toward more inclusive and sustainable forest governance in India. Its successful implementation can lead to a more equitable distribution of forest resources, empowerment of marginalized communities, and the preservation of traditional ways of life.

Biological Diversity Act, 2002

The Biological Diversity Act, 2002 (BDA) is a landmark legislation enacted by the Parliament of India to conserve biological diversity, ensure the sustainable use of its components, and share the benefits arising from its use fairly and equitably.

Key Objectives of the Act

- Preservation of biodiversity
- Responsible utilization of its elements
- Equitable and just distribution of benefits resulting from the utilization of biological resources and knowledge

Key Provisions

- **Access and Benefit Sharing (ABS):** The Act regulates access to biological resources and related traditional knowledge, guaranteeing just and fair distribution of benefits among local communities.
- **Biopiracy prevention:** The Act aims to prevent the unauthorized access to and utilization of biological resources.
- **Threatened species and habitats:** The Act identifies and protects threatened species and their habitats through notification and listing in schedules.
- It empowers the Central Government to make rules for various aspects of its implementation, including access and benefit sharing mechanisms, threatened species management, and biodiversity research.
- It requires prior approval from the National Biodiversity Authority for access to biological resources and associated knowledge.
- It promotes the development of biodiversity management plans at the local level.
- It provides for the protection of traditional knowledge associated with biological resources.

Institutional Structure under the Biodiversity Act, 2002

The Biodiversity Act, 2002, establishes a three-tiered institutional structure to regulate access to biological resources and ensure their conservation and sustainable use. This structure comprises:

National Biodiversity Authority (NBA)

- **Appointed by:** Central Government
- **Functions:**
  - Implement the provisions of the Act.
  - Advise the Central Government on matters relating to the conservation of biodiversity.
  - Regulate access to biological resources by Indian citizens for commercial purposes.
  - Grant approvals for certain activities involving use of biological resources, such as research and bio-discovery.
  - Monitor the implementation of the Act by State Biodiversity Boards.
  - Perform other functions as prescribed under the Act.
  - Can designate institutions as repositories for different categories of biological resources
  - Establishes a National Biodiversity Fund to finance the conservation and sustainable use of biological diversity.
  - Section 6 of the Biological Diversity Act of 2002 requires prior approval from the NBA before applying for intellectual property rights (IPRs). This rule applies to all inventions using or having information on biological materials obtained from India.

State Biodiversity Boards (SBBs)

- **Established by:** State Governments
- **Functions:**
  - Advise the State Government on matters relating to the conservation of biodiversity.
  - Monitor the activities of Biodiversity Management Committees within the State.
  - Perform other functions as delegated by the NBA or prescribed under the Act.

Biodiversity Management Committees (BMCs)

- Established by: Local Self Governments (LSGs) at village, taluka, district, or other levels
- **Composition:**
  - Chairperson - Elected from amongst the members of the LSG
  - Members - Representatives of various stakeholders, including farmers, indigenous communities, NGOs, and scientific institutions
- **Functions:**
  - Prepare Biodiversity Management Plans for their respective areas.
  - Document biodiversity within their jurisdiction.
  - Advise the State Biodiversity Board on matters relating to the conservation of biodiversity.
  - Monitor the use of biological resources within their jurisdiction.
  - Perform other functions as delegated by the State Biodiversity Board or prescribed under the Act.

Challenges

- Some sections of the Act lack clarity and coherence, including the definition of biological resources, the extent of access and benefit-sharing, and the involvement of local communities.
- Difficulty in monitoring and regulating the access and use of biodiversity by various stakeholders, especially in cases of bio-prospecting, bio-piracy, and bio-utilization.
- Limited engagement and awareness among the private sector, researchers, and local communities about the objectives and provisions of the Act, and the need for compliance and benefit-sharing.
- Inadequate institutional capacity and coordination among the National Biodiversity Authority, the State Biodiversity Boards, and the Biodiversity Management Committees, which are responsible for implementing the Act at different levels.
- Exclusion of cultivated medicinal plants from the purview of the Act, which may lead to overexploitation and loss of genetic diversity of these plants.

Way Forward

- Enhancing awareness and capacity building programmes for various stakeholders on the objectives, scope, and implications of the Act, and providing them with adequate guidance and support for complying with the Act.
- Strengthening the documentation and valuation of biological resources and associated knowledge, using participatory and scientific methods, and developing databases and information systems for their effective management and utilization.
- Simplifying and streamlining the approval and clearance process for accessing and using biological resources and knowledge, and ensuring transparency and accountability in the process.
- Establishing and strengthening the monitoring and enforcement mechanisms for the Act, and creating a deterrent effect for potential violators through effective legal action and public awareness.
- Promoting and facilitating the involvement and empowerment of local communities in the conservation and sustainable use of biodiversity, and ensuring that they receive fair and equitable benefits from the use of their resources and knowledge.

Biological Diversity (Amendment) Act, 2023

- This Act amends the Biological Diversity Act of 2002, which was enacted in India to help preserve biological diversity. It also helps India fulfill its obligations under the Convention on Biological Diversity (CBD).
- The amendment in 2023 aims to streamline processes related to the use of biological resources, promote research and the use of traditional Indian medicine systems, and reduce burdens on stakeholders.

Key Changes Made by the Amendment

- **Faster Research and Patent Processes:** The amendment simplifies and speeds up the process of research and obtaining patents related to biological resources in India. This aims to encourage more innovation in the field.
- **Promoting AYUSH Systems of Medicine:** The amendment removes some hurdles for registered AYUSH medical practitioners (practitioners of traditional India medicine like Ayurveda, Yoga, Unani, Siddha, and Homeopathy) and the traditional knowledge holders while using biological resources.
- **Decriminalization:** The amendment decriminalizes certain minor offenses under the original Act.
- **Exemption for Codified Traditional Knowledge:** Users of "codified traditional knowledge" (knowledge documented in ancient texts) are exempted from certain requirements under the Act.
- **Focus on Cultivating Medicinal Plants:** It promotes the cultivation of medicinal plants, reducing collection pressure on wild populations.
- **Powers & Functions of NBA/SBB:**
  - The amendments to Section 7 have conferred authority upon the State Biodiversity Boards (SBBs), compelling Indian entities to fulfill Access and Benefit Sharing (ABS) fees.
  - The transfer of biological resources or associated knowledge no longer necessitates dual approval for research results. However, the requirement for prior approval persists when transferring research results.
    - However, there has been additional clarification of the authorities held by the NBA and SBB.
    - Section 23 provides further details on the powers of the SBBs, particularly in relation to the Benefit Sharing Fee (ABS).

- The introduction of Section 36A grants the NBA the authority to supervise and control access to biological resources originating from foreign nations.

- **Approval for IPR:** Approval is required from foreign entities before they can acquire intellectual property rights (IPR) related to Indian biological resources. On the other hand, Indian entities only need to undergo registration with the National Biodiversity Authority (NBA). However, if these entities plan to commercialize the IPR, prior approval from the NBA becomes mandatory.

The Biological Diversity Act, 2002	Changes made by the Bill
Approval required from NBA (for certain foreign entities) - Entities: (i) foreign individuals, (ii) non-resident Indians, (iii) companies not registered in India, and (iv) companies registered in India and having non-Indian participation in share capital or management - Activities: Obtaining biological resources occurring in India or associated knowledge for: (i) research, (ii) commercial utilisation, or (iii) bio-survey and bio-utilisation	**Approval from NBA** - Entities: Changes the last category to companies registered in India which are "foreign-controlled" companies as under the Companies Act. 2013
Prior intimation required to SBB (for certain domestic entities)	**Prior intimation to SBB**
- Entities: (i) Indian citizens, and (ii) companies registered in India except those which require NBA approval - Activities: Obtaining biological resources occurring in India for commercial utilisation - Exemptions: Use by local people and communities including growers and cultivators of biodiversity, and vaids and hakims practising indigenous medicine	- Activities: access to associated knowledge for commercial utilisation will also require prior intimation - Exemptions: Adds exemptions for: (i) codified traditional knowledge. (ii) cultivated medicinal plants and their products, (iii) AYUSH practitioners: limits the exception to vaids and hakims, and AYUSH practitioners to use for sustenance and livelihood

The Biological Diversity Act, 2002, plays a vital role in safeguarding India's biodiversity and ensuring its sustainable utilization. However, ongoing discussions and efforts are crucial to address challenges and ensure its effectiveness in achieving its objectives in the long run.

National Green Tribunal Act, 2010

The National Green Tribunal Act, 2010 established a special tribunal to deal with cases related to environmental protection and conservation. The act aims to implement the decisions taken at the United Nations conferences on environment and development, and to uphold the right to a healthy environment as part of the Right to Life under Article 21 of the Constitution. The act also provides for relief and compensation for damages to persons and property caused by environmental harm.

National Green Tribunal (NGT)

The NGT is a specialized body equipped with the necessary expertise to handle environmental disputes involving multi-disciplinary issues. This statutory body is not bound by the procedure laid down under the Code of Civil Procedure, 1908, but is guided by principles of natural justice.

- The NGT has its Principal Bench in Delhi and four Zonal Benches located in Chennai, Kolkata, Pune and Bhopal.

Jurisdiction of NGT: The NGT deals with civil cases under the seven laws related to the environment, these include:

- The Water (Prevention and Control of Pollution) Act, 1974
- The Water (Prevention and Control of Pollution) Cess Act, 1977
- The Air (Prevention and Control of Pollution) Act, 1981
- The Environment (Protection) Act, 1986
- The Forest (Conservation) Act, 1980
- The Public Liability Insurance Act, 1991
- The Biological Diversity Act, 2002

Powers of NGT

- **Enforcing Environmental Laws:** The NGT can issue prohibitory orders to stop any activity that is causing or is likely to cause environmental damage.
  - It can also issue directions to authorities and individuals to ensure compliance with environmental laws and regulations.
- **Providing Relief and Compensation:** The NGT has the power to grant relief and compensation to persons affected by environmental violations. This can include compensation for damage to property, health, or livelihood.
- **Suo Moto Powers:** The NGT can take up cases on its own initiative (suo moto) based on media reports, public interest petitions, or other sources of information about environmental violations. This power allows the NGT to address critical environmental issues even if no formal complaint is filed.

- **Procedural flexibility:** Unlike regular courts bound by the Code of Civil Procedure, the NGT can adopt its own procedures, making proceedings faster and less expensive. This allows for quicker resolution of environmental disputes.
- **Monitoring and Compliance:** The NGT can monitor the implementation of its orders and directions and take necessary action to ensure compliance.
- **Power of Civil Court:** The NGT is vested with the powers of a civil court under the Code of Civil Procedure for discharging its functions. This allows them to summon and examine witnesses, impose penalties for non-compliance, and even imprison individuals for contempt of court.
- **Promoting Environmental Awareness:** The NGT can also play a role in promoting environmental awareness by organizing workshops, conferences, and other programs.

Significance of NGT: The NGT has played a crucial role in:

- Providing speedy and effective justice in environmental matters.
- Holding polluters accountable for environmental damage.
- Upholding environmental rights and safeguarding natural resources.

Samit Mehta v. Union of India & Ors case: In this case, concerns were raised about the environmental damage caused by the sinking of a ship carrying coal, fuel oil, and diesel. The **National Green Tribunal** found that the sinking resulted from the respondents' negligence and applied the **"Polluter Pays Principle."**

The tribunal asserted its power to grant compensation for cleaning up the wreckage, emphasizing the **"Precautionary Principle"** and recognizing the right to a clean environment as a fundamental right under Article 21 of the Indian Constitution.

The ship's sinking was deemed equivalent to illegal dumping, leading to pollution in multiple ways. The court imposed a significant environmental compensation of Rs. 100 crores, marking one of the largest compensations ever paid by a private entity to the government.

IGNITE YOUR MIND

Green Guardians: Watchdogs of the Environment: Not just government bodies, but also NGOs play a crucial role. Explore the diverse work of Regulators like NGT and NGOs like Greenpeace India and WWF, and discover how they contribute as powerful green warriors. Who are the watchdogs holding polluters accountable? Meet the National Green Tribunal (NGT) and other regulatory bodies, and understand their role as environmental superheroes.

The NGT Act has been hailed as a landmark piece of legislation for the protection of the environment in India. The Tribunal has been instrumental in resolving several important environmental disputes and has played a significant role in raising awareness about environmental issues.

Protection of Plant Varieties and Farmers' Rights Act, 2001

A legislation aimed at creating a robust system to safeguard plant varieties, ensuring the rights of farmers and plant breeders, and fostering the advancement of new plant varieties.

- The Act is compliant with the International Union for the Protection of New Varieties of Plants (UPOV) Convention.

Objectives

- **Establish an effective system for the protection of plant varieties:** This includes providing breeders with exclusive rights over their new varieties, encouraging investment in research and development and ensuring the availability of improved varieties to farmers.
- **Recognize and protect the rights of farmers:** The Act acknowledges the crucial role farmers play in conserving, improving, and making available plant genetic resources. It grants them specific rights, including the right to save, use, sow, resow, exchange, sell or donate their farm-saved seeds of protected varieties.
- **Encourage the development of new varieties of plants:** By providing a legal framework for plant breeders' rights and farmers' rights, the Act aims to stimulate innovation and development in the agricultural sector.

Rights under the Act

- **Breeders' Rights:** Breeders possess exclusive privileges to cultivate, vend, promote, circulate, import, or export the safeguarded variety. The breeder has the authority to designate an agent or licensee and is entitled to pursue civil remedies in the event of rights infringement.
- **Researchers' Rights:** Researchers have the flexibility to employ any registered variety under the Act for experimentation or research. This encompasses utilizing a variety as an initial source for developing another, though repeated use requires prior permission from the registered breeder.
- **Farmers' Rights:**
  - A farmer who has innovated or developed a new variety is eligible for registration and protection, similar to a breeder of a variety.
  - The registration of a farmer's variety can also be pursued as an existing variety.
  - A farmer retains the right to save, use, sow, re-sow, exchange, share, or sell farm produce, including seeds of a variety protected under the PPV&FR Act, 2001, in the same manner as before the enactment of this Act. However, the farmer is not allowed to sell branded seeds of a variety protected under the PPV&FR Act, 2001.

- Farmers are entitled to recognition and rewards for conserving Plant Genetic Resources, including land races and wild relatives of economic plants.
- The Act includes a provision for compensating farmers in case of the non-performance of a variety.
- Farmers are exempt from paying any fees in proceedings before the Authority, Registrar, Tribunal, or High Court under the Act.

Implementation of the Act

- To implement the provisions of the Act the Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare established the Protection of Plant Varieties and Farmers' Rights Authority on 11" November, 2005.

Protection of Plant Varieties and Farmers' Rights Authority

- The Chairperson is the Chief Executive of the Authority. Besides the Chairperson, the Authority has 15 members, as notified by the Government of India (GOI).
- Eight members serve ex-officio, representing different Departments/Ministries. Additionally, three members are from SAUs and State Governments, with one representative each for farmers, tribal organizations, seed industry, and women organizations associated with agricultural activities, nominated by the Central Government. The Registrar General holds the position of ex-officio Member Secretary for the Authority.
  - **General Functions of the Authority**
    - Enrolling new plant varieties, including essentially derived varieties (EDV) and existing varieties;
    - Creating guidelines for DUS (Distinctiveness, Uniformity and Stability) tests for newly introduced plant species;
    - Formulating methods for characterizing and documenting registered varieties;
    - Establishing mandatory cataloging facilities for all plant varieties;
    - Documenting, indexing, and cataloging farmers' varieties;
    - Acknowledging and rewarding farmers, especially those from tribal and rural communities, involved in conservation and enhancement efforts;
    - Safeguarding genetic resources of economic plants and their wild counterparts;
    - Managing the National Register of Plant Varieties;
    - Overseeing the National Gene Bank to ensure the preservation of plant genetic resources.

The **International Union for the Protection of New Varieties of Plants (UPOV)** is an agreement that protects breeders' rights and prevents farmers from exchanging or reusing saved seeds. The UPOV Convention was established in Paris in 1961.

- The UPOV system of plant variety protection offers protection to plant breeders in other member states. It also encourages foreign breeders to invest in seed production and plant breeding in its own territory.
- **India is not a member of this convention,** as it restricts farmers' freedom to reuse and exchange seeds

Case Study: PepsiCo India vs. Gujarat Potato Farmers

In 2019, an activist Kuruganti filed a complaint with the Protection of Plant Variety and Farmers Rights Authority (PFRA) to revoke PepsiCo's registration for the FL-2027 potato variety. In 2021, the Indian PFRA revoked the patent for PepsiCo's FC5 potato variety, which is used in Lay's chips. However, in January 2024, the Delhi High Court overturned the decision, reversing India's attempt to remove the patent.

The PPV&FR Act has been a subject of much debate, with some arguing that it favors commercial interests over those of farmers. However, it remains a key piece of legislation governing plant varieties and farmers' rights in India.

The Compensatory Afforestation Fund (CAMPA) Act, 2016

The Compensatory Afforestation Fund (CAMPA) Act of 2016 is a law that establishes funds to compensate for the loss of forest land. The funds are used to support afforestation and development activities, and to create nurseries for locally suitable plant species.

Objectives

- To institute a system for gathering and applying funds obtained from user agencies, in accordance with the **Forest (Conservation) Act, 1980,** specifically for compensatory afforestation, net present value of forest land, and related activities.
- To ensure the effective utilization of these funds for undertaking various activities aimed at compensating for forest loss and improving forest quality.

Key Features

- **Two-tier fund structure:** A National Compensatory Afforestation Fund (NCAF) and State Compensatory Afforestation Funds (SCAFs) are established. 10% of the collected funds go to the NCAF, while the remaining 90% are distributed among the SCAFs.

- **Funding sources:** The funds receive money from various sources, including compensatory afforestation levies, additional compensatory afforestation, penal compensatory afforestation, and net present value payments from user agencies.
- **Activities funded:** The funds can be used for a variety of activities, including:

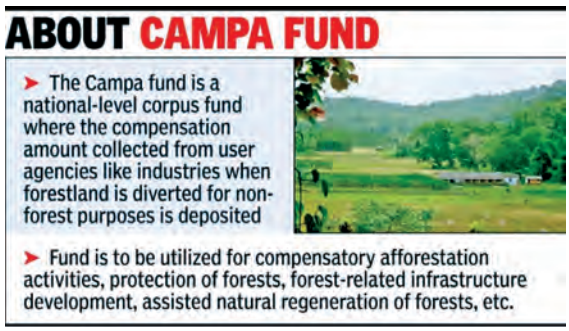

ABOUT CAMPA FUND
The Campa fund is a national-level corpus fund where the compensation amount collected from user agencies like industries when forestland is diverted for non-forest purposes is deposited
Fund is to be utilized for compensatory afforestation activities, protection of forests, forest-related infrastructure development, assisted natural regeneration of forests, etc.

Fig 14.2: CAMPA Fund

  - Creating new forests through plantation and assisted natural regeneration.
  - Protecting existing forests from encroachment and degradation.
  - Improving wildlife habitat and biodiversity conservation.
  - Developing infrastructure like roads, fire lines, and watchtowers for better forest management.
  - Supporting research and training related to forestry.
- **Governance:** National and State CAMPA Authorities are responsible for managing the funds, approving projects, and monitoring their implementation.

Establishment of Funds

- **National Compensatory Afforestation Fund (NCAF):**
  - It was established under the Public Account of India.
  - It receives 10% of all collected funds from user agencies.
  - NCAF is managed by the National CAMPA Authority.
  - **It is primarily used for:**
    - Funding national-level afforestation and forest conservation initiatives.
    - Supporting research and capacity building in forestry.
    - Providing financial assistance to states in case of resource constraints.
- **State Compensatory Afforestation Funds (SCAFs):**
  - It was established under the Public Account of each state and union territory.
  - It receives 90% of all collected funds from user agencies within their jurisdiction.
  - It is managed by the respective State CAMPA Authority.
  - SCAF is primarily used for:
    - Compensatory afforestation and aforestation activities
    - Protection and improvement of existing forests
    - Wildlife conservation and habitat improvement
    - Rehabilitation of degraded forest lands
    - Research and development in forestry
    - Capacity building of forest departments

Sources of Funds

- The funds are credited with various amounts received from user agencies, including:
  - Compensatory afforestation (CA)
  - Additional compensatory afforestation (ACA)
  - Penal compensatory afforestation (PCA)
  - Net present value (NPV) of forest land diverted for non-forest purposes

Institutions to Manage Fund

National Compensatory Afforestation Fund Management Authority (NCA)

The National Compensatory Afforestation Fund Management Authority (NCA) is a statutory body established by the Government of India under the Compensatory Afforestation Fund Act, 2016.

The NCA's functions include:

- To collect, manage, and utilize funds collected as compensatory forest management;
- To monitor the implementation of CAMPA plans;
- To undertake or support afforestation, regeneration, and other forestry activities on degraded forest land;
- To promote research and development in forestry and related fields;
- To perform such other functions as may be assigned to it by the Central Government.

State Compensatory Afforestation Fund Management Authority (SCAMPA)

The State Compensatory Afforestation Fund Management Authority (SCAMPA) is a body established by each state government in India under the Compensatory Afforestation Fund Act, 2016. The SCAMPA is responsible for the management and utilization of funds collected as compensatory forest restoration within the state.

The SCAMPA's functions are similar to those of the NCA, but at the state level. These include:

- To monitor the implementation of CAMPA plans;
- To undertake or support afforestation, regeneration, and other forestry activities on degraded forest land within the state;

Challenges

- There have been delays in the release of funds from both NCAF and SCAFs, hindering timely afforestation and conservation activities.

- Concerns exist about the transparency of decision-making processes regarding fund allocation and project selection.
- Identifying suitable land for afforestation can be challenging due to competing land use demands and resistance from local communities.
- Effective monitoring and evaluation mechanisms are crucial to assess the impact of CAMPA activities and ensure accountability.
- Ensuring meaningful participation of local communities in planning and implementation remains a challenge.
- Long-term maintenance and protection of afforested areas are crucial for ensuring the sustainability of CAMPA projects.

Way Forward

- Simplifying procedures for fund release and project approval can expedite implementation.
- Publishing detailed information on fund allocation, project selection, and progress reports can improve accountability.
- Engaging with local communities and exploring alternative land options can facilitate smoother land acquisition.
- Implementing robust monitoring mechanisms and conducting regular impact assessments are essential.
- Building trust and capacity among local communities through effective communication and collaboration can ensure their active involvement.
- Developing long-term plans for maintenance and protection of afforested areas, including involving communities in their upkeep, is crucial for long-term success.
- Documenting and sharing successful implementation strategies from different states can benefit nationwide efforts.
- Leveraging GIS and remote sensing technologies can enhance monitoring, evaluation, and decision-making processes.

The CAMPA Act is a significant step forward in India's efforts to conserve its forests. However, it is important to ensure that the Act is implemented effectively in order to achieve its full potential.

IGNITE YOUR MIND

Beyond Paper Tigers: Bite or Bark? Are environmental laws enough to ensure a healthy planet, or do we need stronger enforcement mechanisms to make them effective? Discuss the challenges of implementing environmental legislation and brainstorm solutions to ensure these laws don't become mere toothless tigers.

RULES PASSED UNDER ENVIRONMENT (PROTECTION) ACT, 1986

Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms/Genetically Engineered Organisms or Cells, 1989

The Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms/Genetically Engineered Organisms or Cells, 1989 (commonly referred to as "Rules, 1989") fall under the **Environment (Protection) Act, 1986.**

These rules shall be applicable in the following specific cases:

- Sale, sale offers, storage for sale, offers, and any form of transfer, whether with or without compensation.
- Export and import of genetically engineered cells or organisms.
- Production, manufacturing, processing, storage, import, extraction, packaging and repackaging of Genetically Engineered Products.
- Production and manufacturing of drugs, pharmaceuticals, food products, distilleries, tanneries, etc., involving the utilization of microorganisms or genetically engineered microorganisms in some capacity.

Committees under the Rules

- **Recombinant DNA Advisory Committee (RDAC):** Reviews developments in Biotechnology at national and international levels and shall recommend suitable and appropriate safety regulations for India in recombinant research, use and applications from time to time.
  - The Committee functions in the Department of Biotechnology.
- **Review Committee on Genetic Manipulation (RCGM):** Functions in the Department of Biotechnology to monitor the safety related aspects in respect of on-going research projects and activities involving genetically engineered organisms/hazardous microorganisms.
- **Institutional Biosafety Committee (IBSC):** Constituted by an occupier or any person including research institutions handling microorganism/genetically engineered organisms.
  - Nodal point for implementation of the biosafety guidelines and for the interactions within the institution.

- **Genetic Engineering Approval Committee (GEAC):** Functions as a division within the Department of Environment, Forest, and Wildlife to assess activities that entail extensive utilization of hazardous microorganisms and recombinants in research and industrial production, considering environmental implications for approval.
  - Also responsible for approval of proposals relating to release of genetically engineered organisms and products into the environment including experimental field trials.
  - The committee or any person/s authorised by it shall have powers to take punitive action under the Environment (Protection) Act.
- **State Biotechnology Co-Ordination Committee (SBCC):** There shall be a State Biotechnology Coordination Committee in the States wherever necessary. It shall have powers to inspect, investigate and take punitive action in case or violations of statutory provisions through the Nodal Department and the State Pollution Control Board/Directorate of Health/Medical Services.
- **District Level Committee (DLC):** A District Level Biotechnology Committee (DLC) will be established in districts, as needed, under the supervision of District Collectors. The committee's primary responsibility is to oversee compliance with safety regulations in facilities utilizing genetically modified organisms or hazardous microorganisms and their applications in the environment.

The Coastal Regulation Zone (CRZ) Rules, 2019

The Coastal Regulation Zone (CRZ) Rules, 2019 are a set of regulations issued by the Ministry of Environment, Forest and Climate Change to protect and manage the coastal areas of India. The CRZ Rules, 2019 replace the previous CRZ Notification, 2011 and aim to promote sustainable development and conservation of coastal ecosystems, while providing livelihood security to the coastal communities.

Coastal Zone Management Plans (CZMPs)

States are required to prepare Coastal Zone Management Plans (CZMPs) to guide development activities in their coastal areas. This requirement comes from the Coastal Regulation Zone (CRZ) Notification, 2019, issued by the Ministry of Environment, Forests and Climate Change (MoEFCC).

Purpose of CZMPs

- To ensure sustainable development in coastal areas by balancing conservation, livelihood, and economic activities.
- To implement the provisions of the CRZ Notification, 2019, within each state's specific coastal context.
- To identify and protect Ecologically Sensitive Areas (ESAs) within the coastal zone.
- To delineate different CRZ categories (CRZ-I, II, III, and IV) and specify permissible activities in each.
- To facilitate stakeholder participation in coastal management decision-making.

Preparation of CZMPs

- Each state's Coastal Zone Management Authority (CZMA) is responsible for preparing and implementing the CZMP.
- The CZMP preparation process involves consultation with various stakeholders, including government agencies, local communities, environmental NGOs, and experts.
- The CZMP should be based on scientific data, socio-economic studies, and public feedback.
- The final CZMP needs to be approved by the MoEFCC.

Benefits of CZMPs

- Promote balanced and sustainable development in coastal areas.
- Protect ecologically sensitive areas and biodiversity.
- Help mitigate the impacts of climate change and natural disasters.
- Improve resource management and reduce pollution.
- Enhance livelihoods and well-being of coastal communities.

National Coastal Zone Management Authority (NCZMA)

The National Coastal Zone Management Authority (NCZMA) is an ad-hoc body constituted by the Ministry of Environment, Forests and Climate Change (MoEFCC) of the Government of India. Its primary function is to oversee the protection and management of India's coastal zones, which encompass over 7,500 kilometers of coastline along nine maritime states and two Union Territories.

Key roles and responsibilities of the NCZMA

- **Coordinating the actions of State Coastal Zone Management Authorities (SCZMAs):** The NCZMA provides guidance and support to the SCZMAs, which are responsible for implementing the Coastal Regulation Zone (CRZ) Notification, 2011, in their respective states and territories.
- **Examining proposals for changes in the CRZ Notification:** The NCZMA has the authority to consider and approve proposals for changes to the CRZ Notification, which regulates activities in coastal areas.
- **Monitoring and enforcement of the CRZ Notification:** The NCZMA works with the SCZMAs and other relevant authorities to monitor compliance with the CRZ Notification and take action against violations.
- **Promoting integrated coastal zone management (ICZM):** The NCZMA promotes the adoption of ICZM principles, which aim to balance the development needs of coastal communities with the protection of the coastal environment.
- **Providing technical assistance and capacity building:** The NCZMA provides technical assistance and capacity building to the SCZMAs and other stakeholders on matters related to coastal zone management.
- **Prepares CZMPs:** It develops comprehensive plans for different coastal stretches, outlining strategies for:
  - Pollution control
  - Habitat conservation
  - Infrastructure development
  - Livelihood security for coastal communities
- **Grants permits:** It regulates activities like construction, industries, and tourism in coastal areas through a permit system based on CZMP guidelines.
- **Promotes public awareness:** It raises awareness about the importance of coastal conservation and encourages community participation in sustainable management practices.
- **Provides technical guidance:** Supports state governments and stakeholders in implementing CZMPs and addressing coastal management challenges.

Despite its crucial role, the NCZMA has faced criticism for its ad-hoc status and limited resources, which have hampered its effectiveness in carrying out its mandate. A report by the Comptroller and Auditor General of India (CAG) in 2022 noted that the NCZMA's institutional framework does not provide it with the necessary authority and autonomy to function effectively.

**The Coastal Regulation Zone (CRZ) Rules, 2019 have been covered exhaustively in an earlier chapter.

Wetland Conservation & Management Rules (2017)

The Wetland Conservation & Management Rules (2017) are a crucial set of regulations in India aimed at protecting and managing the country's wetlands. The rules were notified in 2017 under the **Environment (Protection) Act, 1986.**

- These aim to conserve, manage, and maintain the ecological character of wetlands while allowing "wise use."
- The rules strengthen the legal and institutional framework for wetland management.

Key Provisions

- **Definition of Wetland:** The Act categorizes a wetland as a region encompassing marshes, fens, peatlands, or bodies of water, whether they are natural or man-made, enduring or temporary. This includes stagnant or flowing water, whether it is fresh, brackish, or saline, and also extends to areas of marine water with a depth not exceeding six meters during low tide.
- **Classification of Wetlands:** The Rules do not classify wetlands but emphasize identifying and notifying wetlands of national and international importance.
- **Prohibited Activities:** The Rules prohibit various activities within notified wetlands, including:
  - Conversion for non-wetland uses like encroachment.
  - Setting up or expanding industries.
  - Discharge of untreated waste and effluents.
  - Construction of permanent structures (except for boat jetties) within 50 meters from the mean high flood level.
  - Poaching.

- **State Wetland Authorities (SWAs)::** The Rules mandate the establishment of a State Wetland Authority (SWA) in each state and union territory to:
  - Prepare an inventory of wetlands.
  - Develop wetland management plans.
  - Issue permits for regulated activities within notified wetlands.
  - Promote awareness about wetland conservation.
- **Wise Use Principle:** The Rules emphasize the "wise use" principle, which promotes the sustainable utilization of wetlands while maintaining their ecological character.
- **National Wetland Committee (NWC):** The National Wetland Committee (NWC) is a body to monitor, advise, and recommend the central government on matters related to wetland conservation and management in India.
  - The NWC is chaired by the Secretary of the Ministry of Environment, Forest and Climate Change (MoEF&CC) and consists of representatives from various ministries, state governments, and expert members.
  - The NWC meets at least once a year and performs the following functions:
    - Monitor the implementation of the rules and the status of wetlands in the country.
    - Provide recommendations to the central government regarding suitable policies and action plans to promote the conservation and sustainable utilization of wetlands.
    - **Recommend the designation of wetlands of international importance under the Ramsar Convention.**
    - Review and approve the integrated management plans prepared by the state wetland authorities for notified wetlands.
    - Address any issues or disputes arising from the implementation of the rules.
- **Integrated Management Plans (IMPs):** Integrated Management Plans (IMPs) are crucial aspects of the Wetland Conservation & Management Rules (2017) in India. They serve as roadmaps for the conservation and management of individual notified wetlands, outlining specific strategies and actions to achieve these goals.
  - **Importance of IMPs:**
    - **Site-specific approach:** IMPs provide a tailored approach to wetland management, considering the unique characteristics and challenges of each individual wetland.
    - **Stakeholder participation:** The development and implementation of IMPs should involve active participation from various stakeholders, including government agencies, local communities, NGOs, and experts. This collaborative approach fosters ownership and ensures the plan reflects diverse perspectives and needs.
    - **Adaptive management:** IMPs are not static documents; they can be revised and updated based on monitoring results and changing circumstances. This adaptability allows for continuous improvement in wetland management practices.
  - **Examples of IMPs in action:**
    - **Nal Sarovar Bird Sanctuary, Gujarat:** The IMP for Nal Sarovar focuses on habitat restoration, waterbird conservation, and sustainable tourism practices.
    - **Vembanad Lake, Kerala:** The IMP for Vembanad Lake addresses issues like pollution control, livelihood diversification for fisherfolk, and mangrove restoration.
    - **Chilika Lake, Odisha:** The Chilika Lake IMP emphasizes integrated management of fisheries, conservation of the lake's unique ecosystem and community-based conservation initiatives.

The Ozone Depleting Substances (Regulation and Control) Rules, 2000

The Ozone Depleting Substances (Regulation and Control) Rules, 2000, is a regulation in India that aims to control the production, consumption, import, and export of Ozone-depleting substances (ODS). It was notified under the Environment (Protection) Act, 1986.

Objectives

- To oversee and manage the manufacturing, usage, inbound and outbound trade of Ozone Depleting Substances (ODS) in alignment with India's commitments under the **Montreal Protocol** on Substances that Deplete the Ozone Layer.
- To safeguard the ozone layer and avert its depletion.

Key Provisions

- **Phasing out of ODS:** The Rules mandate the gradual phasing out of the production, consumption, import, and export of various ODS listed in schedules attached to the rules.
- **Licensing:** Establishments involved in manufacturing, importing, exporting, or trading in ODS require a license from the Competent Authority designated by the Central Government.
- **Quotas:** The Central Government allocates annual quotas for the consumption of certain ODS based on India's Montreal Protocol obligations.
- **Restrictions on trade:** The Rules prohibit the import or export of ODS to or from non-Party countries (countries not signatories to the Montreal Protocol).
- **Reporting and record-keeping:** Manufacturers, importers, and exporters of ODS are required to maintain records and submit reports to the Competent Authority as per specified formats and timelines.
- **Penalties:** The Rules prescribe penalties for violations of the provisions, including imprisonment and fines.

Schedules

- The Rules include various schedules that list:
  - **Schedule I:** ODS to be phased out completely.
  - **Schedule II:** ODS subject to controlled production and consumption with specific phase-out dates.
  - **Schedule III:** ODS permitted for specific essential uses with controlled consumption levels.
  - **Schedule IV:** Activities requiring ODS for servicing or maintenance of existing equipment.
  - **Schedule V:** Timeframes for phasing out ODS in different sectors.
  - **Schedule VI:** List of countries that are Parties to the Montreal Protocol.

Ozone Depleting Substances (Regulation and Control) Amendment Rules, 2019

The Ozone Depleting Substances (Regulation and Control) Amendment Rules, 2019, were published by India's Ministry of Environment, Forest and Climate Change (MoEFCC) on December 18, 2019.

- The rules prohibit the import of HCFC-141b and prohibit the use of it in foam manufacturing. The rules also prohibit the issuance of licenses for importing HCFC-141b from January 1, 2020.
- India took proactive steps to completely eliminate HCFC 141b, a chemical employed by foam manufacturing industries. The nation has successfully phased out HCFC 141b entirely.

IGNITE YOUR MIND

Eco-Detectives on Patrol: Imagine yourself as an environmental detective, patrolling the bustling metropolis of Earth. What are the key environmental laws, like the EPA and Wildlife Protection Act, that act as your rulebook for safeguarding ecological harmony and sustainable development?

ENVIRONMENTAL ORGANIZATIONS

Central Pollution Control Board (CPCB)

The Central Pollution Control Board (CPCB) is a statutory organization under the **Ministry of Environment, Forest and Climate Change (MoEFCC)** of India. It was **constituted in 1974 under the Water (Prevention and Control of Pollution) Act, 1974.** Further, CPCB was entrusted with the powers and functions under the Air (Prevention and Control of Pollution) Act, 1981.

Its main functions are:

- To plan and execute a nationwide program for the prevention and control of water and air pollution.
- To advise the central and state governments on matters related to environmental protection and pollution control.
- To coordinate the activities of the State Pollution Control Boards (SPCBs) and provide them with technical assistance and guidance.
- To set and enforce national standards for water and air quality, industrial emissions and effluents, and noise pollution.
- To collect, analyze, and disseminate data on environmental quality and pollution sources.
- To conduct research and development on various aspects of environmental management and pollution control.
- To promote public awareness and education on environmental issues and pollution prevention.

The CPCB is headed by a chairperson appointed by the central government, and a member secretary who is the chief executive officer of the board. The CPCB has its headquarters in New Delhi, and seven zonal offices and five laboratories across the country.

Key Initiatives

The Central Pollution Control Board (CPCB) has taken numerous initiatives to address various environmental issues in India. Here are some key examples across different areas:

Air Quality

- **Expanding air quality monitoring network:** CPCB has been steadily expanding its network of Continuous Ambient Air Quality Monitoring (CAAQM) stations across the country, providing real-time data for better air quality management.
- **Developing and implementing air quality plans:** CPCB collaborates with state governments to develop and implement State Action Plans for Air Pollution Control (SAPAA), and outlines specific measures to reduce air pollution in identified cities and regions.
- **Promoting cleaner fuels and technologies:** CPCB advocates for the adoption of cleaner fuels like CNG and electric vehicles, and cleaner technologies in industries, to reduce emissions.

Water Quality

- **Strengthening water quality monitoring:** CPCB has expanded its water quality monitoring network across the country, covering various water bodies like rivers, lakes, and groundwater.
- **Developing and implementing river restoration plans:** CPCB collaborates with various stakeholders to develop and implement river restoration plans for polluted rivers like Ganga and Yamuna.
- **Promoting wastewater treatment:** CPCB emphasizes the importance of wastewater treatment through regulations and capacity building programs for municipalities and industries.

Waste Management

- **Promoting waste management hierarchy:** CPCB advocates for following the waste management hierarchy, prioritizing waste reduction, reuse, and recycling over landfilling and incineration.
- **Developing comprehensive waste management plans:** CPCB collaborates with states and cities to develop comprehensive waste management plans, covering municipal solid waste, e-waste, biomedical waste, and other waste streams.
- **Encouraging plastic waste reduction and management:** CPCB implements the Plastic Waste Management Rules, promoting alternatives to single-use plastics and encouraging their effective collection and recycling.

Other Initiatives

- **Promoting cleaner production:** CPCB promotes cleaner production practices in industries to reduce their environmental impact, including resource use, emissions, and waste generation.
- **Raising environmental awareness:** CPCB conducts various awareness campaigns and educational programmes to sensitize the public about environmental issues and encourage responsible behaviour.
- **Research and development:** CPCB undertakes research and development activities to develop new technologies and solutions for environmental challenges.

National Ambient Air Quality Monitoring Programme (NAAQM): The National Air Quality Monitoring Programme (NAAQM) is a country-wide programme that monitors the ambient air quality in India. It was launched in 1985 by the Central Pollution Control Board (CPCB) under the **Ministry of Environment, Forest and Climate Change (MoEFCC).**

Continuous Emission Monitoring System (CEMS): The Continuous Emission Monitoring (CEM) System includes all the required equipment to assess the concentration of gaseous emissions, particulate matter, or emission rates. This is achieved through analytical measurements and a computer program that delivers results in units corresponding to the relevant emission limits or standards.

State Pollution Control Boards (SPCBs)

State Pollution Control Boards (SPCBs) are the state-level authorities that are responsible for implementing the environmental laws and regulations in their respective states. SPCBs have the same functions and powers as the Central Pollution Control Board (CPCB) within their state boundaries.

Some of the Main Functions of SPCBS are

- To plan and execute state-wide programs for the prevention and control of water and air pollution.
- To advise the state government on matters related to environmental protection and pollution control.
- To coordinate with the CPCB and other SPCBs on inter-state issues and policies.
- To grant, refuse, or revoke consent to establish or operate any industry or activity that may cause water or air pollution.
- To monitor, inspect and enforce the compliance of industries and other sources of pollution with the prescribed standards and norms.
- To collect, analyse and publish data on environmental quality and pollution sources.
- To conduct research and development on various aspects of environmental management and pollution control.
- To promote public awareness and education on environmental issues and pollution prevention.

There are 28 SPCBs in India, covering all the states except the Union Territories. The Union Territories are governed by the Pollution Control Committees (PCCs), which have similar functions and powers as the SPCBs.

National Biodiversity Authority (NBA)

The National Biodiversity Authority (NBA) is a statutory body established under the Biodiversity Act, 2002. It functions under the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. The NBA serves as the apex body for the implementation of the Act and plays a pivotal role in:

- **Conservation of biodiversity:** Protecting the diverse variety of life forms in India, including their genetic resources, ecosystems, and associated knowledge systems.
- **Sustainable use of biodiversity:** Ensuring that the use of biological resources for various purposes, such as research, medicine, and agriculture, is carried out in a manner that does not deplete or degrade biodiversity in the long run.
- **Fair and equitable sharing of benefits:** Promoting the fair and equitable sharing of benefits arising from the use of biological resources between various stakeholders, including local communities, indigenous peoples, and researchers.

Key Responsibilities

- **Implement the provisions of the Biodiversity Act:** Formulate and implement policies, plans, and programmes for the conservation of biodiversity.
- **Advise the Central Government:** Provide advice to the Central Government on matters relating to the conservation of biodiversity and the implementation of the Act.
- **Regulate access to biological resources:** Grant approvals for access to biological resources by Indian citizens for commercial purposes, ensuring compliance with the access and benefit-sharing provisions of the Act.
- **Monitor the implementation of the Act:** Oversee the activities of State Biodiversity Boards (SBBs) and ensure effective implementation of the Act at the state level.
- **Perform other functions:** These include designating repositories for different categories of biological resources, promoting public awareness about biodiversity conservation, and collaborating with international organizations on biodiversity-related issues.

Composition

- Chairperson appointed by the Central Government from amongst persons with expertise in the conservation of biodiversity.
- Non-official members with expertise in various fields relevant to biodiversity conservation, such as taxonomy, ecology, economics, law, and social sciences.
- Official members representing relevant ministries and departments of the Central Government.

Indian Council of Forestry Research and Education (ICFRE)

The Indian Council of Forestry Research and Education (ICFRE) is an autonomous organisation or governmental agency under the Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India. It is responsible for forestry research and education in India.

- The ICFRE was created in 1986, under the Central Ministry of Environment and Forests (India), to direct and manage research and education in forestry sector in India.
- ICFRE is headed by a Director General with headquarters at Dehradun.In 1991, ICFRE attained autonomous council status under the Ministry.

Mission

- To undertake strategic and applied research in various aspects of forestry, including:
  - Silviculture (establishment and management of forests)
  - Forest ecology and conservation
  - Forest biotechnology and tree improvement
  - Socio-economic aspects of forestry
  - Wildlife management
- To provide education and training programs for forestry professionals at various levels.
- To disseminate research findings and promote best practices in forest management through extension activities.
- To advise the Government of India on forestry policy and development issues.

Activities

- Conducts research through a network of nine research institutes and five research centers spread across different agro-ecological regions of India.
- Offers undergraduate, postgraduate, and doctoral programs in forestry and related disciplines through its deemed university, the Forest Research Institute (FRI) University.
- Organizes training programmes workshops, and conferences for forest officials, researchers, and stakeholders.
- Publishes research journals, books, and extension materials to disseminate knowledge and best practices.
- Collaborates with national and international institutions on forestry research and development initiatives.

Central Ground Water Authority (CGWA)

The Central Ground Water Authority (CGWA) is a **statutory body** constituted by the Government of India under the Environment (Protection) Act, 1986. It is responsible for the development, management, and regulation of groundwater resources in India.

Mission

- To regulate and control groundwater withdrawal through a permit system, considering factors like recharge rates and aquifer sustainability.
- To promote sustainable groundwater management practices such as rainwater harvesting, artificial recharge, and efficient water use.

- To monitor groundwater levels and quality through a network of observation wells and aquifer mapping.
- To advise the Central Government on matters related to groundwater management and policy.

Activities

- Issues guidelines for groundwater extraction, specifying permissible limits and conditions for different sectors (e.g., agriculture, industry, domestic).
- Grants No Objection Certificates (NOCs) for groundwater withdrawal based on compliance with guidelines and assessment of aquifer availability.
- Monitors groundwater levels through a network of observation wells spread across the country.
- Assesses groundwater quality through periodic water quality testing.
- Promotes rainwater harvesting by providing technical guidance and financial assistance.
- Encourages artificial recharge through various techniques like injection wells and check dams.
- Raises public awareness about the importance of groundwater conservation and sustainable water management practices.

National Mission for Clean Ganga (NMCG)

The National Mission for Clean Ganga (NMCG) is a society registered under the Societies Registration Act, 1860. It is the implementing wing of the National Ganga Council, which is the apex body for the conservation and rejuvenation of the river Ganga and its tributaries.

- The NMCG is responsible for planning, executing, monitoring, and coordinating various projects and activities under the Namami Gange Programme, a flagship initiative of the Government launched in 2014.
- It operates **under the Ministry of Jal Shakti,** Government of India.
- It acted as the implementation arm of National Ganga River Basin Authority (NGRBA) which was constituted under the provisions of the Environment (Protection) Act (EPA),1986.
    - NGRBA has now been dissolved, consequent to constitution of National Council for Rejuvenation, Protection and Management of River Ganga (referred as National Ganga Council) under EPA 1986.

Outlines a five-tier structure at the national, state, and district levels to implement measures aimed at preventing, controlling, and reducing environmental pollution in the Ganga River. Its primary objective is to ensure a consistent and sufficient water flow to rejuvenate the Ganga River.

- **National Ganga Council** under chairmanship of Hon'ble Prime Minister of India.
- **Empowered Task Force (ETF)** on river Ganga under chairmanship of Hon'ble Union Minister of Jal Shakti (Department of Water Resources, River Development and Ganga Rejuvenation).
- **National Mission for Clean Ganga(NMCG).**
    - NMCG has a two tier management structure and comprises Governing Council and Executive Committee. Both of them are headed by Director General, NMCG.
        - The Director General (DG) of NMCG is an Additional Secretary in the Government of India.
- **State Ganga Committees**
    - Much like the framework at the national level, State Programme Management Groups (SPMGs) serve as the executive mechanism for State Ganga Committees.
- Moreover, **Ganga District Committees** are established in each designated district that borders the Ganga River and its tributaries within the respective states.

Key Functions

To achieve the objectives, NMCG carries out the following key functions namely:

- Execute the operational plan of the National Ganga River Basin Authority (NGRBA).
- Execute the National Ganga River Basin Project with support from the World Bank.
- Supervise and manage the implementation of projects sanctioned by the Government of India under NGRBA.
- Undertake additional tasks or responsibilities assigned by the Ministry of Water Resources, River Development, and Ganga Rejuvenation in the domain of Ganga River conservation.
- Formulate and update rules and regulations governing the functioning of the National Mission for Clean Ganga (NMCG), with the authority to add, amend, vary, or rescind them as necessary.
- Accept or provide grants, loans, securities, or property, and assume the management of endowments, trusts, funds, or donations compatible with NMCG's objectives.
- Take all requisite actions and engage in necessary activities to accomplish the objectives of the National Ganga River Basin Authority (NGRBA).

The Mission's Pillars

The NMCG operates on five key pillars:

- **Sewage Treatment Infrastructure:** Building and upgrading sewage treatment plants (STPs) to prevent untreated sewage from entering the river.
- **Industrial Effluent Monitoring:** Stringent regulations and monitoring of industrial waste discharge to minimize industrial pollution.
- **Riverfront Development:** Beautifying and improving the riverfront areas for recreational and cultural purposes.
- **Biodiversity Conservation:** Protecting and restoring the diverse aquatic life and ecosystems of the Ganga basin.
- **Public Awareness:** Educating and engaging communities in Ganga conservation efforts.

Significance

- The NMCG plays a crucial role in:
  - Improving the water quality of the Ganga River, a lifeline for millions of people.
  - Protecting the rich biodiversity of the river ecosystem.
  - Promoting sustainable development along the river basin.
  - Enhancing cultural and spiritual significance of the Ganga for millions of people.

The NMCG's vision for a clean and healthy Ganga is a long-term endeavour. Continued efforts are needed to address existing challenges and ensure the mission's success. By leveraging technology, fostering community participation, and promoting sustainable practices, the NMCG can turn the tide on Ganga's pollution and pave the way for its rejuvenation.

IGNITE YOUR MIND

Green Report Card: Evaluating Progress: Imagine yourself as an environmental auditor. How can we evaluate the effectiveness of environmental laws, policies, and organizations in achieving their goals? Develop criteria and assess the current state of environmental governance in India, identifying areas for improvement.

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

UNEP defines Environmental Impact Assessment (EIA) as a tool used to identify the environmental, social and economic impacts of a project prior to decision-making. It aims to predict environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and options to decision-makers. By using EIA both environmental and economic benefits can be achieved, such as reduced cost and time of project implementation and design, avoided treatment/clean-up costs and impacts of laws and regulations.

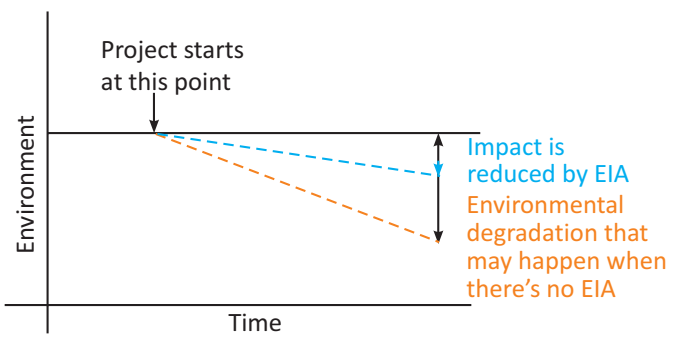


Fig 14.3: Reduced Environmental Impact due to EIA

- **The EIA is a mandatory requirement under the Environmental (Protection) Act, 1986 for 29 categories of developmental activities involving investments of Rs. 50 crores and above.**

Aim: The aims of Environmental Impact Assessment (EIA) include:

- Anticipating environmental impacts during the initial stages of project planning and design.
- Discovering methods to mitigate adverse impacts.
- Tailoring projects to harmonize with the surrounding environment.
- Communicating predictions and alternatives to decision-makers.

Evolution of EIA

- **Origins in the United States (Early 1970s):** The roots of EIA can be traced back to the early 1970s with the implementation of the National Environment Policy Act (NEPA) in the United States in 1969. NEPA laid the foundation for EIA as a mandatory regulatory procedure. It marked the beginning of systematic consideration of environmental impacts in decision-making processes related to development projects.
- **Initial Development in High-Income Countries (Early to Mid-1970s):** The initial development of EIA took place in a few high-income countries, including Canada, Australia, and New Zealand, around 1973-74. These countries played a pioneering role in shaping the concept and practices of EIA.
- **Early Adoption in Developing Countries (1970s-1980s):** Some developing countries also introduced EIA relatively early in their development processes. Examples include Colombia in 1974 and the Philippines in 1978. This indicates a growing awareness of the need for systematic assessment of environmental impacts in diverse global contexts.
- **Global Expansion (Mid-1980s Onwards):** The EIA process gained significant momentum after the mid-1980s. More countries recognized the importance of integrating environmental considerations into development decision-making processes. The global expansion of EIA reflects a broader understanding of its value in promoting sustainable development.
- **World Bank Adoption (1989):** In 1989, the World Bank adopted EIA for major development projects. Under this policy, borrower countries were required to undertake an EIA for projects funded by the World Bank, with the Bank's supervision. This marked a crucial step in mainstreaming EIA at an international level and ensuring that major development initiatives considered their environmental impacts.

- **Widespread Adoption (20th Century):** Over the course of the 20th century, EIA evolved from being a concept in a handful of countries to becoming a formalized and mandated process in many nations. Thirty-seven years ago, there was no EIA but today, it is a formal process in many countries and is currently practiced in more than 100 countries.

History of EIA in India

- **Initiation (1976-77):** The initial steps toward environmental considerations in development projects in India began in 1976-77. The Planning Commission tasked the Department of Science and Technology with examining river-valley projects from an environmental perspective.
- **Expansion to Public Investment Board Projects:** The scope of environmental assessment expanded to cover projects requiring approval from the Public Investment Board.
- **Legislative Backing (1994):** Until 1994, environmental clearance from the Central Government was an administrative decision lacking legislative support. On January 27, 1994, the Union Ministry of Environment and Forests (MoE&F) promulgated an EIA notification under the Environmental (Protection) Act of 1986.
  - This made Environmental Clearance (EC) mandatory for the expansion, modernization, or establishment of new projects listed in the notification.
- **Amendments (1994 Onwards):** Since the initial notification in 1994, there have been more than 12 amendments to the EIA notification. These amendments were likely made to refine and enhance the EIA process based on evolving environmental concerns and feedback from the implementation of the notification.
- **EIA Notification (2006):** In September 2006, the Ministry of Environment and Forests (MoEF) notified new EIA Notification. This legislation expanded the scope of mandatory environmental clearance to various projects, including mining, thermal power plants, river valley projects, infrastructure projects (such as roads, highways, ports, harbors, and airports), and industries, including very small electroplating or foundry units. Notably, the responsibility for clearing projects was shifted to state governments based on the size or capacity of the project.
- **Draft EIA Notification, 2020:** The draft Environment Impact Assessment (EIA) Notification 2020 was issued by the Union Ministry of Environment, Forest and Climate Change (MoEFCC) on March 23, 2020. The draft notification is intended to replace the existing EIA Notification, 2006, under the Environment (Protection) Act, 1986.

Need for EIA in India

- **Protecting India's Diverse Environment:** India boasts a rich biodiversity and unique ecosystems, from the Himalayas to the Thar Desert and the Western Ghats. EIA helps identify potential threats to these ecosystems, allowing for mitigation measures and project modifications to minimize ecological damage.
- **Sustainable Development:** EIA encourages a balanced approach to development, considering both economic needs and environmental concerns. It helps assess the potential impacts of projects on resources like water, air, and soil, enabling the adoption of sustainable practices and minimizing resource depletion.
- **Public Participation and Transparency:** EIA fosters transparency by involving the public in the assessment process. This allows communities potentially affected by projects to voice their concerns and participate in decision-making, leading to more socially responsible outcomes.
- **Compliance with Environmental Laws:** India has a robust set of environmental laws, including the Environment (Protection) Act, 1986. EIA ensures compliance with these laws by requiring project developers to assess potential environmental impacts and implement mitigation measures.
- **Minimizing Risks and Conflicts:** By identifying potential environmental risks early on, EIA helps avoid costly project delays, accidents, and conflicts with communities. This promotes smoother project implementation and reduces the risk of environmental damage.
- **Promoting Sustainable Resource Use:** EIA encourages the efficient use of natural resources like water and energy, minimizing waste generation and pollution. This fosters a more sustainable approach to development and resource management.
- **Adapting to Climate Change:** As India faces the challenges of climate change, EIA plays a crucial role in assessing the vulnerability of projects to climate impacts and incorporating adaptation measures into project design. This ensures the long-term viability of projects and reduces climate risks.
- **Strengthening International Cooperation:** Many international financial institutions and development agencies require EIA for projects they support. Implementing a robust EIA system helps India comply with these requirements and access international funding for sustainable development projects.

The EIA Cycle and Procedures

The EIA process in India comprises various phases, ensuring a comprehensive assessment of environmental impact. These phases are as follows:

- **Project Proposal:**
  - Anyone planning a significant development project must initiate the Environmental Impact Assessment (EIA) process by submitting a detailed proposal to the Impact Assessment Agency (IAA).
  - This proposal should include all accessible pertinent information, such as a land-use map.
  - Once submitted, the proposal triggers the screening stage, which determines whether a full EIA is necessary.

❑ Screening:

- A preliminary assessment to determine if a project necessitates environmental clearance based on statutory notifications.
- Screening often results in a categorization of the project and from this a decision is made on whether or not a full EIA is to be carried out.
- Screening Criteria includes
  - ❒ Scale of Investment
  - ❒ Type of Development
  - ❒ Location of Development
- Environmental clearance is required only if covered by applicable EIA and statutory notifications.

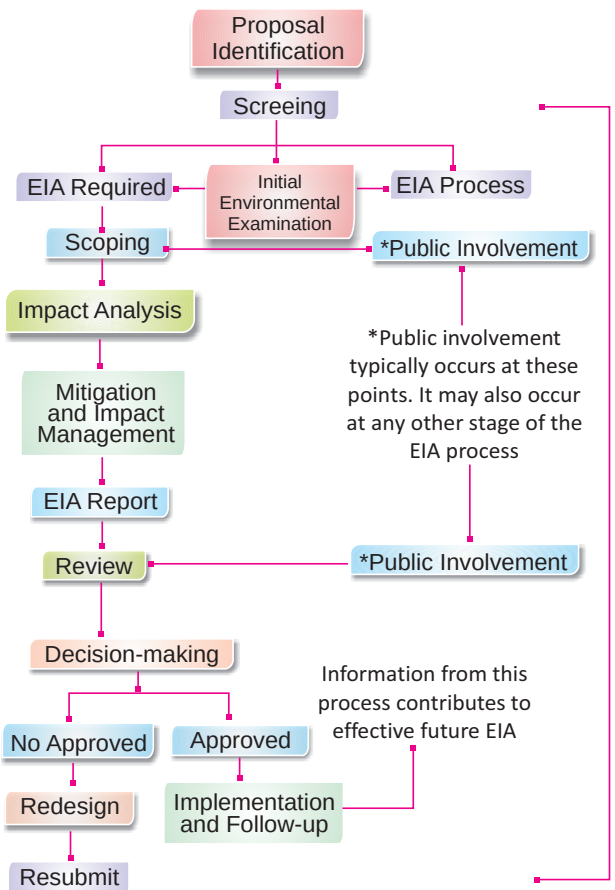


Fig 14.4: The EIA Cycle and Procedures

❑ Scoping:

- The process of defining the terms of reference for EIA, involving collaboration between the consultant, project proponent, and guidance from the Impact Assessment Agency.
- Sector-specific guidelines by the Ministry of Environment and Forests outline significant issues for EIA studies.
- Quantifiable and non-quantifiable impacts are assessed based on various criteria.
- The main EIA techniques used in scoping are baseline studies, checklists, matrices and network diagrams. These techniques collect and present knowledge and information in a straightforward way so that logical decisions can be made about which impacts are most significant. Risk and uncertainty are discussed further in the section Managing uncertainty.

❑ Baseline Data Collection:

- Describing the existing environmental status of the identified study area.
- Site-specific primary data monitored for identified parameters, supplemented by available secondary data.

❑ Impact Prediction:

- Mapping environmental consequences of project aspects and alternatives.
- Assessment of impacts on air, noise, water, land, biological, and socio-economic aspects.
- Emphasis on assessing impacts on breeding grounds, nesting areas, and local communities.

❑ Assessment of Alternatives, Delineation of Mitigation Measures, and Environmental Impact Assessment Report:

- Identifying project alternatives, comparing environmental attributes and ranking for optimum economic benefits.
- Mitigation plan development for selected alternatives, supplemented by an Environmental Management Plan (EMP).
- EIA report providing clear information on environmental scenarios and uncertainties.

❑ Public Hearing:

- The law mandates that the public be informed and consulted regarding a proposed development once the Environmental Impact Assessment (EIA) report is finalized.
- Access to the Executive Summary of the EIA provided to affected parties.
- The affected person may include:
  - ❒ Bonafide local residents
  - ❒ Local associations
  - ❒ Environmental groups active in the area
  - ❒ Any other person located at the project site/sites of displacement
- Opportunity for oral/written suggestions to the State Pollution Control Board granted to those likely to be affected.

❑ Environment Management Plan (EMP):

- Inclusion of mitigation and compensation measures for identified impacts.
- Physical planning with a work program, time schedule, and locations for mitigation and compensation systems.
- Financial plan inclusion in project budget estimates.

❑ **Decision Making:**
- Involves consultation between the project proponent, assisted by a consultant, and the impact assessment authority, assisted by an expert group if necessary.
- Decision on environmental clearance based on evaluation of EIA and EMP.
- The main output report is called an Environmental Impact Statement, and contains a detailed plan for managing and monitoring environmental impacts both during and after implementation.

❑ **Monitoring the Clearance Conditions:**
- Ongoing monitoring during both construction and operation phases.
- Ensures compliance with commitments and validates predictions from EIA reports.
- Corrective action taken if impacts exceed predicted levels, enabling the review of predictions and EMP implementation conditions by the regulatory agency.

Finally, an audit of the EIA process is carried out some time after implementation. The audit serves a useful feedback and learning function.

EIA Components

For an efficient approach, a professionally prepared Comprehensive EIA is generally recommended initially. The nature, location, and scale of the project should dictate the inclusion of specific components in the EIA report:

❑ **Air Environment**
- Identify impact zones through a screening model and establish a monitoring network.
- Monitor ambient air quality within the project's impacted region.
- Assess site-specific meteorological data, including wind speed, direction, humidity, ambient temperature, and lapse rate.
- Estimate air emissions, including fugitive emissions and potential emissions from vehicular traffic.
- Predict changes in ambient air quality due to various emissions using appropriate models.
- Evaluate proposed pollution control devices' adequacy to meet standards.
- Outline mitigation measures at source, pathways, and receptors.

❑ **Noise Environment**
- Monitor existing noise levels within the impact zone.
- Predict future noise levels from the project and related activities.
- Identify impacts from anticipated noise level increases.
- Recommend noise pollution mitigation measures.

❑ **Water Environment**
- Study existing ground and surface water resources within the impact zone.
- Predict impacts on water resources due to project-related water use.
- Quantify and characterize wastewater, evaluating proposed prevention and treatment systems.
- Predict effluent discharge impacts on receiving water bodies.
- Assess water recycling feasibility and propose detailed plans.

❑ **Biological Environment**
- Survey flora and fauna, specifying season and duration.
- Assess flora and fauna within the project's impact zone.
- Evaluate potential damage to terrestrial and aquatic flora and fauna from project emissions.
- Predict biological stresses and delineate mitigation measures.

❑ **Land Environment**
- Study soil characteristics, land use, topography, landscape, and drainage within the impact zone.
- Estimate project impacts on land use, landscape, and drainage.
- Identify treated effluent utility in land application and its impacts.
- Characterize solid wastes and propose waste management options.

❑ **Socio-economic and Health Environment**
- Collect demographic and socio-economic data.
- Gather epidemiological data, including studies on prevalent diseases.
- Project socio-economic and health changes due to the project, including traffic congestion.
- Assess impacts on historical, cultural and archaeological sites.
- Evaluate economic benefits and rehabilitation requirements.

❑ **Risk Assessment**
- Identify hazards using hazard indices, inventory analysis, and Natural Hazard Probability.
- Conduct Maximum Credible Accident analysis.
- Analyze consequences of failures and accidents.
- Conduct Hazard & Operability studies.
- Assess risks based on evaluations and prepare Disaster Management Plans.

❑ **Environment Management Plan**
- Delineate mitigation measures, including prevention, control, and rehabilitation plans.
- Develop a monitoring scheme for compliance.
- Outline implementation plans, including scheduling and resource allocation.

Key Components of Initial Project Description and Scoping

Sectoral Guidelines provided by the Ministry of Environment and Forests (MoEF) highlight crucial environmental considerations for project characteristics.

- An Initial Project Description (IPD) should, at a minimum, furnish the reviewer with comprehensive information for effective project screening and scoping.
- Essential details to be covered in the IPD include:
  - Location and current land use, including conformity with proposed development plans for the area, along with contours.
  - Specifics of the proposed project activity, encompassing project cost.
  - Identification of key project elements throughout preconstruction, construction, and operation phases, as outlined in the attached questionnaire documents.
  - Additional considerations such as off-site activities, associated activities, expected project-induced activities, and representation of project activities through PERT and flow charts delineating unit processes with input-output.
- The IPD may also incorporate:
  - Off-site activities.
  - Associated activities.
  - Expected project-induced activities.
  - Representation of project activities as PERT charts and process flow charts, delineating unit processes with input-output.
- The reviewer's focus, during report assessment, should emphasize crucial aspects related to project location and characteristics after suitable scoping by the project proponent.

Project Location(s)

- Site selection is a strategic approach to minimize the need for mitigation measures.
- Proposed project locations require review based on regulatory and non-regulatory criteria.
- Siting restrictions depend on the sensitivity of the surrounding environment, considering the proximity to ecologically sensitive zones (ESZ) identified by MoEF.

Siting Criteria (Used to Identify and Evaluate Potential Sites for Industries) by Moef Include

- Avoidance of converting prime agricultural/forest land into an industrial site.
- Minimum land acquisition with sufficient space for a green belt, possibly utilizing treated wastewater.
- Provision of space for solid waste storage with potential for future reuse.
- Project layout conformity to the area's landscape without unduly affecting scenic features.
- Creation of an associated township with a phyto-graphic barrier, considering pre-dominant wind direction.

The Proposed Project Location Should also be Evaluated Concerning

- Ambient air, water, and noise quality standards.
- Critically polluted areas.
- Natural disaster-prone areas.
- Ecologically sensitive areas.
- Availability of water and critical infrastructure, such as electricity, roads with adequate width, and capacity.

The reviewer's focus during the assessment should be on crucial aspects related to project location, adherence to regulations, and potential environmental impacts. The scoping process should consider all relevant criteria to ensure sustainable and environmentally responsible project development.

Procedure for Conducting Public Hearing

- **Public Hearing Process:** Those seeking environmental clearance for projects must submit their applications to the relevant State Pollution Control Board.
  - A Public hearing Panel is responsible for supervising and presiding over a Public Hearing.
- **Public Hearing Notice:**
  - The State Pollution Control Board is responsible for issuing a public hearing notice, to be published in at least two widely circulated newspapers in the project's surrounding region. One of these newspapers must be in the vernacular language of the local community. The notice should specify the date, time and venue of the public hearing. The public is invited to share suggestions, views, comments, and objections within thirty days from the publication date of the notification.

What are the steps that are broadly involved in a Public Hearing?

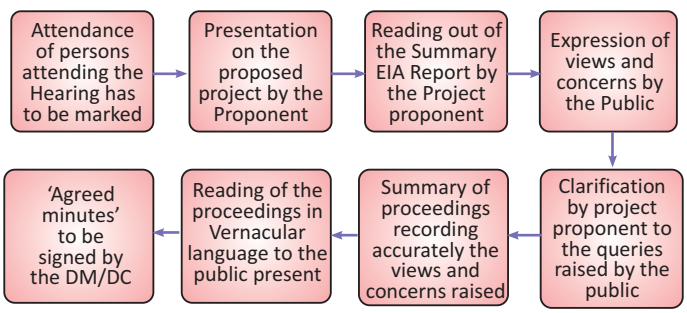

Attendance of persons attending the Hearing has to be marked
Presentation on the proposed project by the Proponent
Reading out of the Summary EIA Report by the Project proponent
Expression of views and concerns by the Public
Clarification by project proponent to the queries raised by the public
Summary of proceedings recording accurately the views and concerns raised
Reading of the proceedings in Vernacular language to the public present
'Agreed minutes' to be signed by the DM/DC

Fig 14.5: Steps involved in Public Hearing

- All individuals, including genuine residents, environmental groups, and others situated at the project site, displacement sites, or potentially affected sites, are eligible to participate in the public hearing. They can provide oral or written input to the State Pollution Control Board.

- A Panel consisting of the District Magistrate/ the District Collector / the Deputy Commissioner or his or her representative (not below the rank of an Additional District Magistrate), assisted by a representative of the concerned State Pollution Control Board, are responsible for supervising and presiding over a Public Hearing.

❑ **Composition of the Public Hearing Panel:** The Public Hearing Panel may include the following members:

- Representative of the State Pollution Control Board
- District Collector or their nominee
- Representative of the State Government handling the subject
- Representative of the State Government's Environmental Department
- Up to three representatives from local bodies such as Municipalities or Panchayats
- Up to three senior citizens from the area nominated by the District Collector

This procedure aims to ensure transparency, public participation, and thorough consideration of environmental concerns in the decision-making process for granting environmental clearance for projects.

EIA Notification, 2006

The 2006 Environment Impact Assessment Notification has decentralized the approval process for developmental projects, categorizing them into two groups: Category A and Category B.

For 'Category A' projects, a national-level appraisal is conducted by the Impact Assessment Agency (IAA) and the Expert Appraisal Committee (EAC), while 'Category B' projects undergo appraisal at the state level.

State Level Environment Impact Assessment Authority (SEIAA) and **State Level Expert Appraisal Committee (SEAC)** are established to grant clearance to Category B projects.

After the 2006 Amendment, the EIA cycle involves four stages:

❑ Screening

❑ Scoping

❑ Public hearing

❑ Appraisal

Mandatory environmental clearance is required for Category A projects, eliminating the need for the screening process. On the other hand, Category B projects go through the screening process and are further classified into two types:

❑ Category B1 projects (Mandatory, requiring EIA)

❑ Category B2 projects (Exempt from EIA)

As a result, Category A and Category B1 projects undergo the complete EIA process, while Category B2 projects are excluded from the comprehensive EIA process.

Category A And B Projects In EIA

The EIA Rules divide the projects into two categories, A and B, based on their size and impact on natural and artificial resources.

❑ **Category A projects** require permission on behalf of the Central Government from the Ministry of Environment and Forests, based on the opinion of an **Expert Appraisal Committee (EAC)** created by the Central Government for this particular purpose.

- For example- harbours, airports, nuclear power and related projects, individual projects, construction or expansion of ports, primary metallurgical industries (like steel, iron, copper), etc.

❑ Projects falling under **Category B** require the approval of a State EIA, based on the opinion of a **State Expert Appraisal Committee (SEAC)** formed in the EIA Notification 2006.

- However, the state government will first classify if the B project falls under B1 or B2 category. B1 projects will require preparation of EIA reports while remaining projects will be termed as B2 projects and will not require EIA report.
- For example- Building and Construction Projects, Manufacturing Industries, Irrigation Projects, Small Hydroelectric Projects

Draft EIA Notification, 2020

In 2020, the Ministry of Environment, Forest and Climate Change (MoEF & CC) proposed revisions to the Environment Impact Assessment (EIA) Notification of 2006, aiming to update the environmental assessment framework in India. These proposed changes, outlined in the Draft EIA Notification 2020, were intended to replace EIA Notification of 2006

❑ **Streamlined Public Hearings:** A notable aspect of the Environmental Impact Assessment (EIA) Mechanism is its emphasis on public participation. The 2020 draft recommends a reduction in the notice period for public hearings from 30 to 20 days, a modification justified by the Ministry of Environment, Forest and Climate Change (MoEFCC) as aligned with technological advancements such as the proliferation of the internet and mobile telephony.

❑ **Project Categorization and Exemption:** The draft categorizes projects into A, B1, and B2, resulting in the exemption of certain projects from public scrutiny. Unlike A and B1 projects, Category B2 projects do not necessitate mandatory Environmental Clearance (EC).

- Diverse Exempted Projects: Projects falling under the exempted category encompass offshore and onshore oil and gas exploration, hydroelectric projects up to 25 MW, irrigation projects spanning 2,000 to 10,000 hectares, small and medium cement plants, specified acids production, MSMEs in certain industries, inland waterway projects, expansion or widening of highways, aerial ropeways in ecologically sensitive areas, and specified building construction and area development projects up to 1,50,000 sq. m.

- **Post-approval Environmental Safeguards:** Post-clearance compliance requires strict adherence to EIA report regulations after project approval to mitigate further environmental damage.
- **Shift to Annual Compliance Reporting:** The revised draft suggests an annual compliance report submission, departing from the 2006 notification, which mandated reports every six months. Concerns arise regarding the extended period potentially enabling project proponents to conceal adverse consequences.
- **Project Proponent-Generated Compliance Reports:** The compliance report will be exclusively prepared by project proponents, lacking external oversight and review, raising doubts about the accuracy of the submitted information.
- **Absence of Public Reporting for Non-Compliance:** The EIA Notification 2020 excludes public reporting of violations and non-compliance. Reports will only be accepted from the violator-promoter, government authority, Appraisal Committee, or Regulatory Authority.
- **Post-facto Clearance:** The draft introduces the concept of 'post-facto clearance,' allowing projects operating without environmental clearance to regularize or apply for clearance. Some legal opinions, exemplified in the Alembic Pharmaceutical vs. Rohit Prajapati case in April 2020, question the validity of environmental law supporting ex post facto clearance.
- **Penalties for Non-compliant Firms:** Firms violating establishment terms, if clearance is required, will face penalties as outlined in the draft.

Criticism: Faced significant criticism from environmental groups, activists and even some government bodies. Concerns included:

- **Reduced consultation time:** The draft drastically reduced the time allotted for public hearing on proposed projects, from 30 days to a mere 20 days. This was seen as hindering proper public scrutiny and informed participation.
- **Exempting certain projects:** The notification exempted several categories of projects from public hearings, including modernization of irrigation projects, building constructions, and national highway expansions. Critics argued this silenced potentially impacted communities and undermined transparency.
- **Ex-post facto clearances:** The draft allowed for "ex-post facto" environmental clearances, meaning projects already underway could get clearance afterward. This raised concerns about bypassing necessary safeguards and potentially harming the environment.
- **Inadequate consideration of climate change:** Critics argued the notification lacked specific provisions for assessing a project's impact on climate change and vulnerability, despite India's international commitments under the Paris Agreement.
- **Reduced public access to information:** The draft made it harder for the public to access crucial environmental information related to proposed projects.
- **Potential for industry bias:** Concerns were raised about the notification potentially favoring industries and neglecting the delicate balance between development and environmental protection.

Current status: The 2020 draft Environment Impact Assessment (EIA) Notification was criticized by many environmentalists and conservationists, who called for its withdrawal. The EIA Notification, 2006 remains the governing legislation for EIAs in India.

Challenges of India's EIA

- **Lack of Public Awareness:** Many communities potentially affected by projects lack awareness about EIA and their rights to participate. This can lead to their concerns being ignored and unfair project decisions. Unavailability of EIA reports in local languages can further exacerbate this issue.
  - For example, A tribal community in Odisha may be unaware of an upcoming mining project's EIA report being available only in English, hindering their ability to understand potential impacts and voice concerns.
- **Lax enforcement and loopholes:** Concerns exist about the enforcement of EIA regulations, with some projects potentially circumventing the process altogether or exploiting loopholes. This can lead to inadequate environmental assessments and mitigation measures.
- **Lack of expertise and capacity:** Availability of qualified professionals to conduct comprehensive EIAs, especially in specialized fields, can be limited. This can result in inaccurate assessments and inadequate mitigation plans.
  - A report found that there is a shortage of qualified and experienced staff in the MoEFCC and the State Pollution Control Boards (SPCBs) to conduct and review EIAs. The report also found that the EIA consultants were not accredited or regulated by any authority and often lacked the necessary expertise and experience.
- **Politicization and corruption:** There are concerns about potential political interference and corruption in the EIA process, leading to biased assessments and approvals for projects with significant environmental risks.

- A study of the EIA process in India found that there were instances of political interference and corruption in the EIA process, leading to biased assessments and approvals for projects with significant environmental risks. Some projects were influenced by the vested interests of the project proponents, the EIA consultants, the regulators, or the politicians.

- **Inadequate public participation:** The current public participation process might not be effective in ensuring meaningful engagement and addressing community concerns. This can lead to social conflicts and project delays.
  - A study found that the public participation process was often limited to a one-time public hearing, which was poorly conducted and attended. The public hearing was also often held at an inconvenient time or location, or without proper notice or information. The public comments were also not adequately considered or incorporated in the final EIA report or the environmental clearance decision.
- **Focus on clearance over assessment:** The focus might be more on obtaining environmental clearance rather than conducting a thorough and objective assessment. This can compromise the effectiveness of the EIA process.
- **Integration with other environmental frameworks:** There might be a lack of integration between EIA and other environmental frameworks, leading to inconsistencies and duplication of efforts.
  - The EIA process is not coordinated with the other environmental regulations, such as the Forest Conservation Act, the Wildlife Protection Act, the Coastal Regulation Zone Notification, or the National Green Tribunal Act.

IGNITE YOUR MIND

Beyond Paperwork: Real-world Impact: Is EIA just a bureaucratic hurdle, or does it truly have the power to safeguard the environment? Discuss the effectiveness of EIA in mitigating environmental damage and explore potential ways to strengthen its impact for a greener future.

Case Studies on Environmental Impact Assessment (EIA)

While the effectiveness of EIA in India is debated, there have been some notable success stories where it has demonstrably led to positive environmental outcomes. Here are a few examples:

- **Gujarat RIL Refinery Expansion Project:** This case, though initially controversial, is often cited as an example of a comprehensive EIA leading to significant environmental improvements. The EIA identified potential impacts on air, water, land, and biodiversity and recommended mitigation measures like upgrading local infrastructure, providing healthcare, and managing pollution. While concerns remain about implementation, the project did incorporate many of the EIA's recommendations.
- **Mumbai-Ahmedabad High-Speed Rail Corridor:** This project's EIA, conducted jointly by India and Japan, was lauded for its detailed assessment of potential impacts on various environmental components, including noise, wildlife, and water resources. The EIA also explored alternative alignments and mitigation measures, ultimately leading to a revised route with reduced environmental impact.
- **Integrated Coal Mine Project in West Bengal:** This project faced opposition due to potential impacts on forests and tribal communities. However, the EIA process facilitated public participation and led to the incorporation of significant mitigation measures like wildlife corridors, afforestation programs, and livelihood support for affected communities. The project ultimately received environmental clearance with stricter conditions.
- **River Linking Project:** While the project ultimately faced concerns and was shelved, its EIA process is considered a success in terms of comprehensiveness and public participation. The EIA assessed potential impacts on various aspects, including water availability, ecology, and socio-economic factors. This information, though not used for the project itself, has contributed to broader discussions on water resource management in India.

Way Forward

- **Strengthening public participation and transparency:** Ensure meaningful public involvement at all EIA stages, with clear criteria for consultation, disclosure, and grievance redressal mechanisms.
- **Preventing post-facto clearance and violations:** There should be strict adherence to prior environmental clearance, stringent penalties for non-compliance, and timely enforcement. Enhance compliance reporting, monitoring, and involve independent agencies for verification.
- **Improving data quality and availability:** Steps should be taken in order to ensure accurate, reliable, and updated data through standardized scientific methods. Promote the use of secondary data sources for validation, such as satellite imagery and GIS.
- **Enhancing capacity and expertise:** By ensuring that project stakeholders possess adequate capacity and expertise. Set minimum qualifications and accreditation for EIA practitioners, provide regular training programs, and encourage best practices and innovation.

EIAs are an important tool for ensuring that development projects are planned, designed, and implemented in a way that minimizes their negative impacts on the environment.

Environmental Supplement Plan (ESP)

An Environmental Supplemental Plan (ESP) is an environmentally beneficial project or activity that is not required by law, but that an alleged violator of Environmental Impact Assessment Notification, 2006 agrees to undertake as part of the process of environmental clearance. While not legally mandated, the ESP is part of the environmental clearance process.

- The term "environmentally beneficial" signifies that an ESP aims to remediate, enhance, protect the environment, or mitigate risks to public health and the environment.

Proposals within ESP

- Violating companies could proceed with their operations by settling a financial penalty.
- The incurred penalty would subsequently be allocated to fund an "environmentally beneficial project or activity" benefiting a specific group of stakeholders affected by the violations.

Positives of ESPs

- **Can lead to environmental improvements:** ESPs can fund projects that improve air and water quality, protect endangered species, and restore habitats. These projects can have a positive impact on the environment, even if they do not fully offset the negative impacts of the company's activities.
- **Can be more flexible than regulation:** ESPs can be tailored to the specific needs of a company and the environment in which it operates. This can make them more effective than traditional command-and-control regulation, which can be inflexible and one-size-fits-all.
- **Can encourage innovation:** ESPs can encourage companies to develop new technologies and practices that reduce their environmental impact. This can lead to long-term environmental benefits.
- **Can improve public relations:** Companies that participate in ESPs can improve their public image and build goodwill with communities.

Negatives of ESPs

- **Can be used to avoid compliance with regulations:** Some companies may use ESPs as a way to avoid complying with environmental regulations. This can undermine the effectiveness of environmental laws and regulations.
- **Difficult to measure effectiveness:** It can be difficult to measure the environmental benefits of ESPs, and it is often unclear whether they actually offset the negative impacts of the company's activities.
- **Can create a false sense of security:** ESPs may create a false sense of security that a company is doing enough to protect the environment, even if the ESP is not actually effective.
- **Can be unfair to companies that comply with regulations:** Companies that comply with environmental regulations may be at a competitive disadvantage to companies that use ESPs to avoid compliance.

ESPs can be a useful tool for improving environmental quality, but they are not a panacea. It is important to carefully consider the potential positives and negatives of ESPs before deciding whether or not to participate in one.

Strategic Environmental Assessment

Instead of focusing solely on individual projects, Strategic Environmental Assessment (SEA) takes a broader approach by analyzing the potential environmental impacts of policies, plans, and programs in the early stages of decision-making.

- This allows for considering environmental factors before major choices are made and when various options are still available.

EIA	SEA
Takes place at end of decision-making cycle	Takes place at earlier stages of decision making cycle
Reactive approach to development proposal	Pro-active approach to development proposals
Identifies specific impacts on the environment	Also identifies environmental implications, issues of sustainable development
Considers limited number of feasible alternatives	Considers broad range of potential alternatives
Limited review of cumulative effects	Early warning of cumulative effects
Emphasis on mitigating and minimizing impacts	Emphasis on meeting environmental objectives, maintaining natural systems
Narrow perspective, high level of detail	Broad perspective, lower level of detail to provide a vision and overall framework
Well-defined process, clear beginning and end	Multi-stage process, overlapping components, policy level is continuing, iterative
Focuses on standard agenda, treats symptoms of environmental deterioration	Focuses on sustainability agenda, gets at sources of environmental deterioration

- Compared to Environmental Impact Assessments (EIAs) that happen later in the process, SEA is a proactive way to integrate environmental considerations into high-level decision-making.
- While EIAs are widely used, they have limitations in minimizing environmental impacts. They occur later in the decision-making process, after key decisions and directions are already determined.

SEA is not mandatory in India, even though the country has a long history of environmental impact assessment (EIA) at the project level. India's experience with SEA has been ad-hoc and voluntary, mostly driven by external funders or agencies.

PARIVESH: A Web-Based Platform for Environmental Clearances in India

PARIVESH is a crucial web-based platform in India for streamlining the process of acquiring environmental clearances. Launched in 2018 by the Ministry of Environment, Forests and Climate Change (MoEFCC), it has revolutionized the way proposals are submitted, tracked, and monitored for environment, forest, wildlife, and Coastal Regulation Zone (CRZ) clearances.

Key Objectives of PARIVESH

- **Enhance efficiency, transparency, and accountability:** By automating the clearance process and making information readily available online, PARIVESH has brought in a new level of transparency and accountability.
- **Reduce turnaround time:** The platform has significantly reduced the time taken to get clearances, from over 150 days in 2019 to less than 70 days in 2022 for central-level clearances.

Fig 14.6: Features of PARIVESH

- **Improve ease of access:** PARIVESH provides a user-friendly interface for proponents and authorities alike, making it easier to navigate the clearance process.
- **Standardize processes:** The platform ensures consistency in the clearance process across different regions and states.

Features of PARIVESH

- **Role-based workflow:** Different users, such as proponents, consultants and government officials, have specific roles and access levels within the platform.
  - PARIVESH facilitates a role-based workflow for various stakeholders involved in the EIA process, including:
    - Project proponents
    - Government agencies
    - Expert committees
    - Public
- **Single window interface:** Proponents can submit all their applications and documents through a single portal.
- **Real-time tracking:** Users can track the status of their proposals at every stage of the process.
- **GIS integration:** The platform leverages GIS technology to map project locations and assess environmental impacts.
- **Advanced data analytics:** PARIVESH uses data analytics to identify trends and improve the clearance process.
- **Increased Public Participation:** PARIVESH promotes public participation in the EIA process by providing:
  - **Access to project information:** Project details, EIA reports, and public hearing notifications are available online.
  - **Online submission of comments and suggestions:** The public can participate in the process by submitting feedback on proposed projects.

Benefits of PARIVESH

- **For proponents:** Reduced costs and time delays, improved transparency and predictability, easier access to information.
- **For authorities:** Streamlined workflow, improved efficiency and decision-making, better data management.
- **For the environment:** More sustainable development practices, reduced environmental impact of projects.

PARIVESH 2.0

- The government launched PARIVESH 2.0 in June 2023, further enhancing the platform's features and functionalities.
- The new version offers a more intuitive interface, improved data security, and integration with other government systems. It is expected to make the clearance process even faster and more efficient.

PARIVESH has been a game-changer for environmental clearances in India. It has made the process more efficient, transparent, and accountable, benefiting all stakeholders involved.

Social Impact Assessment (SIA)

Social Impact Assessment (SIA) is a systematic process used to identify, analyze, and evaluate the potential social impacts of a project, plan, or policy. It aims to understand how these interventions might affect individuals, communities, and society as a whole, considering both positive and negative consequences.

Objectives of SIA

- **Promote informed decision-making:** By providing insights into potential social impacts, SIA helps decision-makers consider the social dimension alongside other factors during project planning and approval processes.
- **Minimize negative social impacts:** Identifying potential negative impacts early on allows for the development of mitigation strategies to reduce or avoid harm to affected communities.
- **Maximize positive social benefits:** SIA can help identify opportunities to enhance positive social outcomes associated with a project, promoting social development and well-being.
- **Ensure social justice and equity:** By considering the diverse needs and perspectives of stakeholders, SIA promotes fair and equitable outcomes for all affected groups.

Assessment Process

- The phases of the SIA process are outlined in the SIA process overview and explained in detail in the Social Impact Assessment Guideline (March 2018).
- In accordance with the Strong and Sustainable Resource Communities Act 2017 (SSRC Act) and SIA Guideline, the SIA must address 5 key matters:
  - Community and stakeholder engagement
  - Workforce management
  - Housing and accommodation
  - Local business and industry procurement
  - Health and community well-being.

Key Steps in SIA

- **Scoping:** Defining the scope of the assessment, including the project boundaries, potential impacts to be considered, and stakeholders involved.
- **Baseline data collection:** Gathering information about the existing social, cultural and economic conditions of the affected communities.
- **Impact identification and assessment:** Analyzing the potential social impacts of the project, both positive and negative, on various aspects like:
  - Livelihoods and economic opportunities
  - Health and well-being
  - Cultural heritage and community values
  - Access to resources and services
  - Gender equality and social inclusion
- **Public consultation:** Engaging with stakeholders throughout the process to gather their concerns, suggestions, and traditional knowledge.
- **Mitigation and monitoring:** Developing strategies to address negative impacts and monitor the effectiveness of mitigation measures over time.

Benefits of SIA

- **Promotes sustainable development:** Ensures social considerations are integrated into development processes, leading to more equitable and inclusive outcomes.
- **Reduces social conflicts:** Identifying and addressing potential negative impacts early on can help prevent social unrest and conflicts.
- **Enhances project performance:** By considering social factors, projects can be designed and implemented more effectively, potentially leading to improved social license to operate.
- **Strengthens stakeholders' relationships:** Engaging with stakeholders through SIA fosters trust, transparency, and collaboration.

Challenges of SIA

- Limited resources and expertise: Conducting comprehensive SIAs can be resource-intensive, requiring skilled practitioners and adequate funding.
- **Data availability and quality:** Gathering reliable social data, particularly in remote or marginalized communities, can be challenging.
- **Power dynamics and stakeholder engagement:** Ensuring meaningful participation of all stakeholders, especially vulnerable groups, can be complex.
- **Integration into decision-making:** Effectively integrating SIA findings into decision-making processes can be challenging due to competing priorities and political considerations.

Way Forward

- Developing and applying a common framework and guidelines for SIA that are based on best practices, principles, and indicators.
- Adopting a holistic and systemic approach to SIA that considers the interrelationships and interactions among social, environmental, and economic impacts.

- Enhancing the data collection and analysis methods for SIA, such as using mixed methods, participatory tools, and digital technologies.
- Strengthening the stakeholder involvement and empowerment in the SIA process, such as using co-design, co-production, and co-evaluation methods.
- Increasing the accountability and transparency of the SIA process and results, such as using feedback mechanisms, reporting systems and impact management tools.

Overall, Social Impact Assessment plays a crucial role in promoting socially responsible development. By fostering informed decision-making, mitigating negative impacts, and maximizing positive social outcomes, SIA contributes to building a more just, equitable and sustainable future.

IGNITE YOUR MIND

The Road Ahead: Charting a Greener Course: What are some key steps individuals, communities, and governments can take to ensure stronger environmental protection and a more sustainable future? Brainstorm innovative solutions and chart a course for a greener tomorrow, where humans and nature thrive in harmony.

CONCLUSION

The environmental laws, policies, organizations, and environmental impact assessments (EIAs) form a crucial web for protecting our planet. These tools work in concert to ensure sustainable development, minimize environmental damage, and promote responsible resource management. While challenges remain, ongoing efforts at various levels– from local communities to international collaborations – offer hope for a future where environmental protection and economic growth thrive in harmony. As responsible citizens, staying informed, participating in discussions, and advocating for robust environmental safeguards are essential to create a healthy and sustainable world for generations to come.

Environment, Society and Ethics

15

In the intricate web of human civilization, the environment serves as both a cradle and a canvas for societal development. As societies evolve, their interactions with the natural world shape not only their immediate surroundings but also the ethical fabric that guides their actions. The intersection of environment, society, and ethics forms a critical nexus where the choices and behaviors of individuals and communities profoundly impact the health of ecosystems, the well-being of human populations, and the overall sustainability of our planet.

This chapter delves into the complex relationship between environment, society, and ethics, exploring how human values, norms, and beliefs influence environmental attitudes and behaviors. From ancient philosophical teachings to contemporary debates on environmental justice and sustainability, we embark on a journey to understand the ethical dimensions of environmental issues and the societal responsibilities they entail. Through interdisciplinary lenses, we examine the interplay between human societies and the natural world, probing the moral dilemmas, ethical frameworks, and cultural perspectives that shape our collective stewardship of the Earth.

ENVIRONMENTAL ETHICS

If preserving the integrity of a particular ecosystem requires actions such as extinguishing natural fires, culling feral animals, or managing overpopulated species, are these actions morally permissible or necessary? Is it morally acceptable for farmers in non-industrial countries to employ slash and burn techniques to clear land for agriculture? Considering a mining company that has conducted open-pit mining in previously pristine areas, does the company bear a moral responsibility to restore the landform and surface ecology? What is the ethical value of a human-restored environment compared to its original, natural state?

Environmental ethics explores a range of questions, some of which are personal dilemmas individuals face in specific situations, while others are broader challenges confronting communities and societies. Additionally, abstract inquiries delve into the moral worth and significance of the natural environment and its non-human elements. Let us try to delve into such intriguing issues.

Environmental ethics is the discipline in philosophy that studies the moral relationship of human beings to, and also the value and moral status of, the environment and its non-human contents.

It examines questions about how humans should interact with the environment, what ethical responsibilities humans have towards nature, and the moral values inherent in the environment itself. These inquiries often involve discussions about conservation, sustainability, biodiversity, animal welfare, and the rights of future generations to inherit a healthy planet.

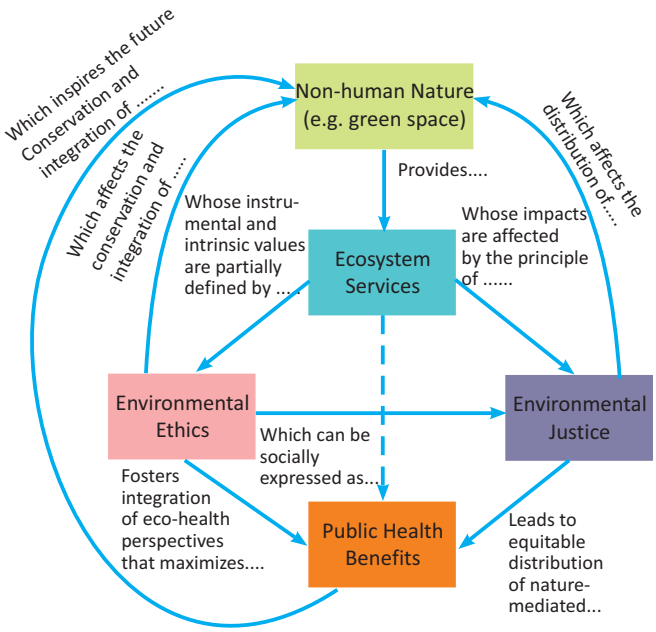

Non-human Nature (e.g. green space)
Provides....
Ecosystem Services
Whose instru-mental and intrinsic values are partially defined by ....
Whose impacts are affected by the principle of .....
Which inspires the future Conservation and integration of .....
Which affects the conservation and integration of ....
Which affects the distribution of ....
Environmental Ethics
Which can be socially expressed as...
Environmental Justice
Fosters integration of eco-health perspectives that maximizes....
Public Health Benefits
Leads to equitable distribution of nature-mediated...

Fig 15.1: Benefits of Ecosystem Services

Need for Environmental Ethics

The necessity for environmental ethics stems from humanity's significant impact on the natural world and the ethical questions it raises.

- **Understanding Environmental Ethics:** Environmental ethics offers a framework to address moral dilemmas related to environmental issues like pollution, resource depletion, habitat destruction, and climate change.
- **Guiding Decision-Making:** By examining the moral implications of human actions on the environment, environmental ethics directs decision-making towards sustainable practices that honor the intrinsic value of nature and foster the well-being of ecosystems, species, and future generations.
- **Debating Intrinsic Value:** Environmental ethics debates whether harming the environment is wrong merely because it endangers human well-being or if it's also wrong because nature and its components possess intrinsic value deserving respect and protection.

- **Human Impact and Resource Demand:** Human activities cause environmental pollution, aggravated by the escalating demand for necessities like food and shelter, disrupting the natural balance and harming the environment. Technological progress further contributes to resource depletion and environmental degradation.
- **Urgency for Environmental Ethics:** Given the swift environmental decline and the imperative for inter-generational equity, integrating environmental ethics into governance structures becomes paramount.

Eco-Ignorant to Earth Avengers: Bridging the Knowledge-Action Gap

How can we transform ourselves from bystanders to empowered Earth Avengers, wielding knowledge and passion to protect our planet? Explore the gap between environmental awareness and real action, and brainstorm solutions to ignite the spark for active participation in climate action.

Environmental Ethics and Its Principles

Numerous principles guide how we value our environment, each emphasizing different aspects of environmental ethics. Here are the key principles found in various theories:

- **Anthropocentrism:** Human beings are deemed the most significant entities, with other living beings seen as supportive elements for human survival. This principle branches into weak and strong anthropocentrism.
- **Non-Anthropocentrism:** Values every object and animal in nature, believing in the intrinsic worth of all elements sustaining themselves in the environment.
- **Psychocentrism:** Attributes greater value to humans due to their more developed and complex mental capacities compared to other elements in the environment.
- **Biocentrism:** Values all living beings and emphasizes ecological balance on the planet, holding ecological and political significance.
- **Ecocentrism:** Ecocentrism emphasizes the value of the natural world, including plants, animals, and elements like water and soil, aiming to diminish human centrality and highlight the interconnectedness of all environmental components. This is in line with the principle of Vasudhaiva Kutumbakam, which promotes unity and interconnectedness among all beings.
- **Holism:** Regards environmental systems as interconnected whole rather than isolated parts, recognizing their inherent value.
- **Resourcism:** Considers nature valuable solely for the resources it provides, endorsing its exploitation.
- **Instrumental Value:** Values beings based on their utility in serving human needs.
- **Intrinsic Value:** Recognizes the value of a being for its own sake, independent of its usefulness.
- **Aesthetic Value:** Attributes value to a being based on its appearance or beauty.
- **Speciesism:** Justifies human superiority and the exploitation of animals by humans.
- **Animal Welfare:** Ensures humane treatment of animals, safeguarding their well-being.
- **Moral Considerability:** Acknowledges intrinsic value in every being, obligating moral treatment in all interactions.
- **Animal Liberation or Animal Rights:** Advocates for laws protecting animal life and welfare.

Eco-Feminism

Oppression, hierarchy, and the spiritual **interconnectedness with nature** stand as central tenets within ecofeminism. Ecofeminists argue that the degradation of nature by human actions and the subjugation of women by men stem from political ideologies and social norms where **both women and nature are objectified or controlled.**

Cultural vs. Social Interpretations: While cultural ecofeminists emphasize the inherent connection rooted in women's reproductive and nurturing roles, social ecofeminists attribute it to societal hierarchies that confine women primarily to domestic spheres.

Chipko Movement and Eco-Feminism

The Chipko Movement and ecofeminism share common ground in their advocacy for environmental conservation and social justice, particularly in relation to the role of women in environmental activism.

- The Chipko Movement, originating in India in the 1970s, involved primarily rural women who took action to protect forests from deforestation by embracing trees slated for logging.
- These women played a central role in the movement, highlighting their close connection to the land and their concern for its preservation.
- Both Chipko and Eco-feminism movements highlight the interconnectedness of environmental issues and social inequalities, advocating for holistic approaches to sustainability that prioritize the well-being of both humans and the environment.

Overall, the Chipko Movement serves as a powerful example of how women's leadership and environmental activism can intersect, aligning closely with the principles and goals of eco-feminism in advocating for a more just and sustainable world.

Other Movements	Connection to eco-feminism
Bishnoi Movement	Advocates for environmental conservation and protection of trees and wildlife, aligning with ecofeminist principles of valuing nature and opposing its exploitation.

Chipko Movement (Apiko)	Involves women hugging trees to prevent deforestation, highlighting the intersection of gender and environmental activism. It exemplifies ecofeminist principles by addressing both women's empowerment and environmental protection.
Narmada Bachao Andolan	Protests against large dams and their adverse impacts, advocating for the rights of women and nature. It highlights the interconnectedness of social and environmental injustices, aligning with ecofeminist goals of equity and sustainability.

ENVIRONMENTAL JUSTICE

Environmental justice refers to the equitable treatment and active participation of all individuals, regardless of their race, ethnicity, socio-economic status, or national origin, in the creation, implementation, and enforcement of environmental laws, regulations, and policies.

Equitable treatment ensures that no community faces an unfair burden of negative environmental impacts resulting from industrial, municipal, or commercial activities, or from government actions at the federal, state, or local levels.

- Environmental justice upholds the sanctity of the Earth, acknowledging the interconnectedness of all life forms and advocating for protection from ecological harm.
- It insists on unbiased public policies that respect and serve all communities equally, without discrimination.
- It promotes ethical and sustainable use of land and resources for the benefit of current and future generations.
- It demands universal safeguards against nuclear activities and toxic waste disposal to safeguard clean air, water, land, and food.
- Environmental justice supports the self-determination of all peoples, encompassing political, economic, cultural, and environmental aspects.
- It calls for an end to the production of harmful substances and holds producers accountable for cleanup efforts.
- It advocates for ecological policies that rebuild urban and rural areas in harmony with nature, respecting cultural diversity and ensuring equitable access to resources.
- Environmental justice opposes non-consensual medical procedures and experiments, especially on marginalized communities.
- It stands against the destructive practices of multinational corporations.
- Environmental justice opposes military exploitation of lands, peoples, and cultures.
- It emphasizes the inclusion of social and environmental issues in education, promoting cultural diversity and awareness.
- Environmental justice encourages individuals to adopt sustainable lifestyles, minimizing resource consumption and waste production for the well-being of the planet and future generations.

Fig 15.2: Environmental Justice

Landmark Environmental Justice Cases and Environmental Law Doctrines

The Supreme Court of India has adopted the principles of sustainable development, acknowledging the necessity of striking a balance among the environment, society, and economics. While not a novel concept, sustainable development has garnered increased importance in the twenty-first century, particularly with the rise of global industrial and information societies. It endeavors to fulfill present needs without jeopardizing the capacity of future generations to fulfill their own requirements, as articulated in the Brundtland Report.

Some of the Major Environmental Doctrines are

- **Intergenerational Equity Principle:** The principle of intergenerational equity underscores the importance of development meeting the current generation's needs without compromising the ability of future generations to meet their own needs.
  - The Supreme Court, in the case of Bombay Dyeing & Mfg. Co. Ltd. vs. Bombay Environmental Action Group, endorsed this principle, ensuring that present generations do not exploit resources to the detriment of future generations.
- **Doctrine of Absolute Liability:** In the landmark case of Union Carbide Corporation v. Union of India, the Supreme Court established the doctrine of absolute liability.
  - This doctrine holds enterprises strictly liable for any harm resulting from inherently dangerous or hazardous activities, without exemptions.

- **Polluter Pays Principle:** The polluter pays principle, gaining recognition in recent years, holds that those who pollute the environment must bear the costs of pollution and its cleanup, regardless of fault.
  - The Supreme Court affirmed this principle in the case of Vellore Citizens Welfare Forum v. Union of India, aligning it with the goal of remedying environmental harm.
- **Precautionary Principle:** The Supreme Court, in the Vellore Citizens Forum case, outlined the precautionary principle's key aspects.
  - It emphasizes anticipating, preventing, and addressing environmental degradation, not postponing measures due to scientific uncertainty, and burdening the party undertaking an action to demonstrate its benign nature.
- **Public Trust Doctrine:** Based on the principle that certain resources are vital to society as a whole and should not be subject to private ownership, the Public Trust Doctrine ensures protection and management of resources in the public's best interests.
  - In M.C. Mehta v. Kamal Nath and Others, the Supreme Court affirmed this doctrine as an inherent part of the law.
  - The Supreme Court, in cases such as Rural Litigation and Entitlement Kendra v. State of UP and Vellore Citizen's Welfare Forum, recognized sustainable development as essential for eradicating poverty and improving human life while respecting ecological limits.

Rivers Ganga and Yamuna as Living Entities

The Uttarakhand High Court in 2017 had recognized the Ganga and Yamuna rivers, along with their tributaries, as "juristic/legal persons" with the status of legal entities, in accordance with **Articles 48-A and 51A(g)** of the Constitution of India. This unprecedented decision stems from the urgent need to address the imminent threat to the existence of these rivers. It marks the first time in India's history that a river has been granted legal recognition.

IGNITE YOUR MIND

Environmental Justice Warriors: Fighting for the Voiceless

Who are the environmental justice warriors, and how are they using legal tools to fight for the rights of communities disproportionately impacted by environmental issues? Explore landmark legal cases that set precedents for environmental justice and discuss the ongoing struggles for equitable and sustainable solutions.

Environmental Rights Recognised by Judiciary

The proactive involvement of the judiciary in safeguarding the environment is apparent in numerous landmark rulings, outlined as follows:

- **The Right to a Wholesome Environment:** In the Charan Lal Sahu case, the Supreme Court affirmed that the right to life guaranteed by Article 21 of the Constitution encompasses the right to a wholesome environment.
  - In the Damodhar Rao v. Municipal Corporation of Hyderabad case, the court invoked Constitutional provisions under Articles 48A and 51A(g) to assert that environmental pollution would violate the fundamental right to life and personal liberty enshrined in Article 21.
- **Judicial response to Public Nuisance:** In the Ratlam Municipal Council v. Vardhichand case, the Supreme Court's ruling underscored the social justice aspect of the rule of law.
  - It held statutory authorities accountable for fulfilling their obligations to abate public nuisance and ensure a pollution-free environment, even in the face of budgetary constraints. This case also affirmed Public Interest Litigation (PIL) as a constitutional duty of the courts.
- **Judiciary intervening and providing compensation to the victims:** In the Delhi gas leak case (M.C. Mehta v. Union of India), the Supreme Court established two significant legal principles.
  - Firstly, it reaffirmed the court's authority to grant remedial relief, including compensation, for proven violations of fundamental rights such as Article 21.
  - Secondly, it introduced the concept of "no-fault" liability (absolute liability) for industries involved in hazardous activities, significantly influencing liability and compensation laws in India.
- **Fundamental Right to Water:** The fundamental right to water in India has evolved through judicial interpretation. In the Narmada Bachao Andolan v. Union of India and Ors. case, the Supreme Court upheld that water is a fundamental necessity for human survival and an implicit component of the right to life, human rights, the right to a healthy environment, and sustainable development as enshrined in Article 21 of the Constitution.
- **Forest definition:** In the T.N. Godavarman Thirumulpad Case (1996), the Supreme Court adopted a broad interpretation of forests, extending to all areas recognized as such by statute, regardless of their reservation status under the Forest Conservation Act.

The judiciary in India has played a pivotal role in recognizing environmental rights by interpreting them as fundamental rights under the Constitution, particularly the right to a healthy environment within Article 21. Through landmark judgments, it has established principles like the "polluter pays" and precautionary principles, driving environmental protection. Additionally, the judiciary's proactive interventions through PILs have led to significant environmental governance reforms, emphasizing accountability and promoting a culture of environmental stewardship.

CLIMATE JUSTICE

Climate justice is a concept that reframes global warming as an ethical and political concern rather than solely an environmental or physical phenomenon.

- It recognizes that climate change can disproportionately affect underprivileged populations, impacting various aspects such as social, economic, and public health.
- These impacts are often unevenly distributed among different groups, including the rich and poor, women and men, and older and younger generations.
- Whether it's extreme weather events or rising sea levels, marginalized communities often bear the brunt of climate change effects.

The Center for Climate Justice at the University of California has outlined six key principles of Climate Justice:

- **Equitable Transition:** This involves shifting from fossil fuel-based economies to fair, sustainable, and renewable energy systems.
- **Intersectional Justice:** Recognizing the unequal impacts of climate change on marginalized communities, especially those with low income, and acknowledging their minimal contribution to the issue.
- **Indigenous Leadership:** Acknowledging the disproportionate impact of climate change on Indigenous communities and their crucial role in climate action due to their intimate connection with their environments.
- **Community Resilience and Adaptation:** Emphasizing the importance of community-based solutions that uphold principles of social justice and equity, such as food sovereignty and local empowerment in climate action.
- **Natural Climate Solutions:** Approaching climate solutions holistically by incorporating practices like regenerative farming, agroforestry, and urban gardening.
- **Climate Education and Engagement:** Stressing the significance of widespread education and involvement in climate issues, particularly in understanding climate justice as vital for addressing the root causes of climate change.

Climate justice demands equitable responses to climate change, prioritizing the needs of vulnerable communities and ensuring fairness in mitigation and adaptation efforts. It requires recognizing historical injustices and taking bold action to address systemic inequalities, promote resilience, and build sustainable societies.

(**Note:** This topic is more comprehensively covered in Chapter Climate Change Mitigation).

The Turnaround Story of Amur Falcon

In Nagaland, the successful conservation efforts for the Amur Falcon stand as a beacon of environmental awareness. Through community engagement and education programs, locals have embraced the importance of preserving habitat and ending hunting practices. Conservation initiatives have led to a remarkable rebound in Amur Falcon populations, showcasing the power of collective action for biodiversity protection.

YOUTH ENGAGEMENT IN CLIMATE ACTION

Climate change has ushered in a new era of uncertainty about the future, with its impacts becoming increasingly pronounced over time. Amidst this uncertainty, one thing remains clear, the responsibility of safeguarding the Earth for today's children and future generations rests in our hands.

KEY ACTION AREAS
DESIGN YOUTH-INCLUSIVE NDC PROCESSES AT THE COUNTRY LEVEL
SUPPORT THE DEVELOPMENT OF YOUTH-LED NDC IMPLEMENTATION PROJECTS
STRENGTHEN CLIMATE CHANGE CAPACITY BUILDING FOR YOUNG PEOPLE
ENCOURAGE YOUTH PARTICIPATION IN GLOBAL NDC PARTNERSHIP ACTIVITIES

Fig 15.3: Key action areas for Youth participation in Climate change initiative

Fridays for Future:

- The Global Climate Movement, spearheaded by FFF, is a dynamic student-driven initiative advocating for urgent action on climate change through active campaigning and advocacy efforts.
- Inspired by **Swedish teenager Greta Thunberg's solo protest** in front of the Swedish parliament in 2018, the movement gained momentum rapidly, Greta Thunberg's dedication led to her being honored with the **Right Livelihood Award 2019,** also known as Sweden's alternative Nobel Prize.
- Recognized for its significant role in raising awareness about the devastating impacts of climate change, the FFF movement was awarded the **Champion of the Earth award** for inspiration and action.
- The movement's primary objectives include exerting moral pressure on policy makers to head scientific evidence and take decisive action to limit global warming.
- Key demands include keeping the global temperature rise below 1.5°C compared to pre-industrial levels, ensuring climate justice and equity, and following the best available science to address the climate crisis.

Demand For Delhi: In the context of Delhi, it advocates preservation of the **Aravallis**, improved sewage management to prevent pollution of the **Yamuna River,** increased public participation in policymaking processes, and enhanced environmental education in schools.

ENVIRONMENTAL ETHICS AND CONTEMPORARY DEBATES

Sustainable Business Practices

Sustainable business practices involve strategies that prioritize environmental, social, and economic responsibility to ensure long-term viability while minimizing negative impacts. Businesses aiming to adopt sustainability practices can explore various strategies to achieve their goals like:

- **Collaborate with Nonprofits:** Businesses new to sustainability can overcome challenges by partnering with nonprofit organizations aligned with their goals. These organizations provide expertise and resources to kickstart sustainability initiatives and offer valuable support even in the early stages.
- **Educate Employees:** Successful sustainability initiatives often involve educating employees about relevant issues and involving them in the process. This fosters buy-in, boosts morale, and empowers employees to contribute meaningfully to sustainability efforts through various educational activities and training programs.

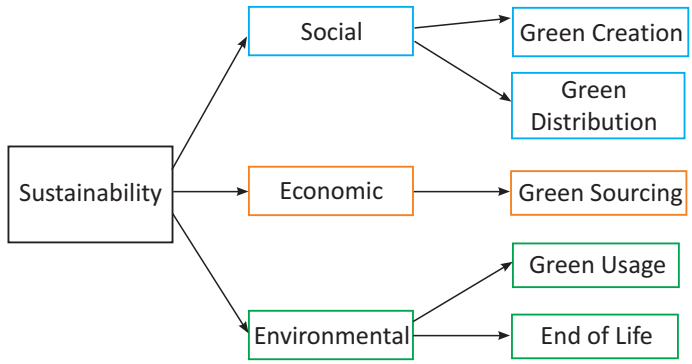


Fig 15.4: Components of sustainabilit

- Promote Volunteerism: Encouraging volunteerism among employees is another effective way to engage them in sustainability. Providing paid time off for volunteering or organizing company-wide volunteer events fosters a sense of community involvement and social responsibility.
- Optimize Supply Chain: Analyzing and optimizing the supply chain can uncover opportunities to enhance sustainability. This includes responsibly sourcing materials, reducing natural resource consumption, and minimizing carbon emissions through measures such as smart energy usage and transportation optimization.

Business Responsibility and Sustainability Framework (BRSF)

The **Business Responsibility and Sustainability Framework** provides a structured approach for companies to integrate responsible business practices and sustainability principles into their operations. It encompasses strategies for environmental conservation, social welfare, ethical governance, and stakeholder engagement, aligning with global sustainability goals.

Embracing sustainable business practices is essential for companies to thrive in an increasingly interconnected and resource-constrained world. By prioritizing environmental stewardship, social responsibility, and ethical governance, businesses can create value for all stakeholders while safeguarding the planet for future generations.

Corporate Social Responsibility (CSR)-Environmental Impact

Environmental Corporate Social Responsibility (CSR) aims to mitigate negative impacts on the environment resulting from business operations. This includes activities focused on energy and water conservation, waste management, recycling, emissions reduction, and implementing eco-friendly office and travel policies. These initiatives not only benefit the environment but also offer financial advantages.

Advantages of environmental CSR: They include

- Reduced business risk, enhanced reputation, and cost savings opportunities.
- Simple measures such as turning off lights and equipment when not in use, minimizing water usage, and reducing paper waste can yield significant savings.
- Additionally, demonstrating environmental responsibility can attract environmentally conscious customers, thereby increasing revenue.

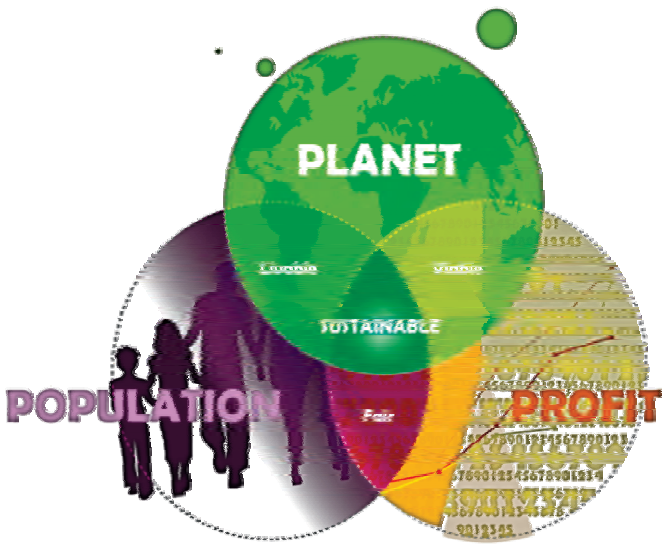


Fig 15.5: Pictorial representation of Sustainability

Example

- Tata Group, one of India's largest conglomerates, has demonstrated a strong commitment to Corporate Social Responsibility (CSR) through various initiatives across sectors. One notable example is the Tata Power's Community Development Trust (TPCDT) in Jamshedpur.
  - Established in 2009 TPCDT focuses on improving the quality of life for communities living in and around Tata Power's operational areas.
- **ITC- Water Stewardship:** Through the IWDP, ITC works with local communities to implement watershed development activities in water-stressed regions across India.

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Business Unusual: Unconventional Paths to Sustainability:

Forget traditional business models, think innovation and impact! Explore how companies can embrace unconventional initiatives, like adopting renewable energy or promoting sustainable products, to contribute significantly to environmental well-being.

By integrating environmental considerations into their operations, companies can mitigate their ecological footprint and contribute positively to environmental conservation. Through CSR efforts focused on environmental impact, businesses not only fulfill their ethical obligations but also drive meaningful change towards a more sustainable future.

Environmental, Social, and Governance (ESG) Criteria

- ESG, an acronym for Environmental, Social, and Governance, encompasses the standards used to assess an organization's impact in these areas.

ESG CONSIDERATIONS IN INVESTMENT DECISIONS

Environmental	Social	Governance
Renewable fuels	Health & safety	Ethical standard & corporate behaviour
Climate risk	Human rights	Board diversity & structure
Greenhouse gas emissions	Working conditions	Stakeholder engagement
Energy efficiency	Employee relations	Executive compensation
Water management	Inclusion & diversity	Shareholder rights
Recycling processes	Impact on local communities	
Population growth		
Emergency preparedness		

Fig 15.6: ESG Considerations in Investment Decisions

- It represents a holistic approach that companies adopt to promote sustainable business practices and create long-term value, going beyond financial metrics.
- The ESG criteria aim to deliver benefits that go beyond financial gains, benefiting society and various stakeholders, including investors, customers, employees, and communities.
- While ESG is a voluntary initiative for companies, many receive explicit requests from investors or shareholders to disclose comprehensive ESG information.
- Companies typically communicate ESG issues to stakeholders through publicly available annual reports, following specific criteria established by the ESG standards and frameworks they adhere to.
- ESG investors utilize the data from these reports to assign ESG ratings to companies, allowing for comparisons of their relative ESG performance.

The integration of Environmental, Social, and Governance (ESG) factors into business practices has become imperative for companies seeking long-term success and resilience. By prioritizing ESG considerations, companies can mitigate risks, enhance brand reputation, attract investment, and drive sustainable growth.

Differences between ESG and CSR have been presented below:

Aspect	ESG (Environmental, Social, and Governance)	CSR (Corporate Social Responsibility)
Focus	External impact on environmental, social and governance factors.	Internal and external social responsibility initiatives and actions.
Reporting Approach	Requires standardized, comparable criteria and metrics.	Less standardized, more organization specific and qualitative.
Data Compilation	Often involves third party ESG data compilers.	Typically self-monitored and reported by the company.
Metrics Availability	Tangible data paints and metrics for evaluation.	Less concrete, more qualitative measures.
External Validation	May involve external validation of reported data.	Primarily internally focused, with limited external validation.

IGNITE YOUR MIND

Green Giants or Eco-Villains? Decoding Corporate Responsibility

Can corporations leverage their power for good through sustainable practices and genuine social responsibility, or are they destined to remain profit-driven eco-villains? Unpack the concept of Environmental, Social, and Governance (ESG) criteria and analyze its influence on corporate decision-making towards a greener future.

Beej Bachao Andolan

Founded in the late 1980s by farmer and activist Vijay Jardhari in Jardhargaon, Uttaranchal, the BBA movement aims to conserve traditional seeds and promote sustainable agriculture practices in the region.

- Traditional farming practices like "baranaja" are upheld in areas like the Ramasirain valley of Uttarkashi district, cultivating indigenous crops such as red rice and thapchini.
- With efforts to preserve over 150 paddy and 170 rajma varieties, the BBA champions sustainable pest control using natural methods. It serves as a sustainable agriculture model, ensuring food security and environmental sustainability.

IGNITE YOUR MIND

Plants & People: A Story of Interdependence

Unravel the fascinating world of ethno-botany, where the ancient bond between plants and cultures is studied. How can this knowledge bridge the gap between scientific understanding and traditional practices, fostering a deeper connection with nature and promoting sustainable conservation?

THE FUTURE OF ENVIRONMENTAL ETHICS

With the growing concern for environmental preservation and its impact on our planet, the field of environmental ethics is poised for sustained relevance. However, it's future trajectory remains uncertain, though there are indications of several potential developments

- **Environmental Ethics in Political Context:** The evolution of environmental ethics will be closely tied to shifts in political initiatives aimed at addressing environmental challenges.
  - As governments and policymakers implement measures to mitigate environmental harm, ethical considerations will play an increasingly integral role in shaping policy decisions.
- **Corporate Responsibility and Environmental Ethics:** There is a growing recognition of the role that businesses must play in addressing environmental issues.
  - As consumers become more environmentally conscious, there is a potential for businesses to lead the way in environmental stewardship.
  - This may lead to a convergence of environmental ethics and business ethics, as corporate entities grapple with ethical responsibilities towards the environment.
- **Scientific Advancements and Ethical Perspectives:** Advancements in scientific understanding of the environment will continue to inform environmental ethics discourse.
  - Whether through insights into ecosystem dynamics or evidence of environmental crises, scientific developments will shape ethical perspectives on our environmental obligations.
- **Intersections with Other Ethical Domains:** It's crucial to acknowledge that the environment permeates all aspects of human existence, influencing various ethical domains such as just war theory, distributive justice, and human rights.

- For instance, considerations of global distributive justice are inherently linked to the disparate impacts of climate change on populations worldwide, affecting aspects like housing, sanitation, health, and livelihoods. Thus, environmental considerations are indispensable in addressing questions of justice on both local and global scales.

Way Forward

- **Education and Awareness:** Promote education and awareness programs to instill environmental values and ethics from an early age.
- **Policy Integration:** Integrate environmental ethics into policymaking at all levels to ensure sustainable development.
- **Corporate Responsibility:** Encourage businesses to adopt ethical practices that prioritize environmental conservation and sustainability.
- **Community Engagement:** Foster community participation in environmental decision-making processes to ensure inclusivity and accountability.
- **Global Collaboration:** Advocate for international cooperation to address environmental challenges and promote ethical stewardship of natural resources.

MISCELLANEOUS CONCEPTS

Ethical Issues and Climate Change

While climate change is typically viewed as an environmental or physical issue, its resolution hinges on addressing a complex web of ethical concerns like:

- **Disproportionate Impact:** Developing nations and marginalized communities often face a heavier burden due to their vulnerability and limited resources.
- **Climate Migration and Displacement:** Environmental changes force people to move, increasing insecurity and impacting dignity.
- **Unequal Responsibility Distribution:** Industrialized countries historically emit the most greenhouse gases, yet everyone bears the negative consequences.
- **Climate Justice for Indigenous Peoples:** Traditional lands and ways of life are threatened by climate change, raising justice concerns.
- **Technological Inequity:** Access to climate-friendly technologies and clean energy solutions varies greatly among countries and communities.

Climate Change Denialism

It refers to the rejection or skepticism of the scientific consensus on climate change, particularly regarding it being anthropogenic (primarily human activities) and its impacts on the environment and society.

- Denialists often downplay or dismiss the evidence supporting climate change, including temperature records, greenhouse gas measurements, and observed changes in ecosystems and weather patterns.
- They may also promote misleading information, cherry-pick data, or question the integrity of climate scientists and their research.
  - This can be partly attributed to the decision of the US government in 2020 to pull out of the Paris deal, which might have given a fillip to the denialist paradigm. (Although, the US later rejoined the Paris agreement in 2021).
- Climate change denialism can take various forms, ranging from outright denial of the phenomenon's existence to questioning the extent of human influence or the urgency of taking action.
- It is often motivated by political, ideological, or economic interests, as well as a reluctance to accept the implications of climate change for policy-making and economic activities.

It's important to note that skepticism and critical inquiry are fundamental aspects of scientific discourse, and legitimate scientific debate and disagreement exist within the scientific community. However, climate change denialism typically refers to the rejection of well-established scientific evidence without sound scientific basis.

Environmental ethics provide a moral compass for navigating the complex relationship between humans and the environment. By integrating ethical principles into our actions and policies, we can strive for a harmonious coexistence with nature. Embracing environmental ethics is not just a moral imperative but also essential for ensuring the well-being of current and future generations. Through education, policy integration, corporate responsibility, community engagement, and global collaboration, we can pave the way for a sustainable and equitable future.

Ethics and Equity are at the core of the debate of climate change. Debate has to move from Climate Change to Climate Justice. — PM Narendra Modi.

Appendices

16

PROTECTED AREAS IN INDIA

1. National Parks(NP)/Wildlife Sanctuaries(WLS)/Tiger Reserve(TR)/ Ramsar Sites(RS)

Note: NP = National Park; WLS = **Wildlife Sanctuaries; TR = Tiger Reserve; BS = Bird Sanctuary; CSR =** Conservation Reserve; CMR = Community Reserve

State/Union Territory	National Parks	Wildlife Sanctuaries	Tiger Reserve	Ramsar Site
Andaman & Nicobar Islands	Campbell Bay NP (1992) Galathea Bay NP (1992) Mahatma Gandhi Marine (Wandoor) NP (1983) Middle Button Island NP (1987) Mount Harriet NP (1987) North Button Island NP (1979) Rani Jhansi Marine NP (1996) Saddle Peak NP (1987) South Button Island NP (1987)	Barren Island WLS Mangrove Island WLS Narcondam Island WLS Ranger Island WLS Coral WLS Saltwater Crocodile (Lohabarrack) WLS	-	
Andhra Pradesh	Papikonda NP (2008) Rajiv Gandhi (Rameswaram) NP (2005) Sri Venkateswara NP (1989)	Nagarjuna Sagar-Srisailam (1978) Coringa WLS Sri Lankamalleswara WLS	Nagarjunsagar Srisailam TR	Kolleru Lake
Assam	Dibru-Saikhowa NP (1999) Kaziranga NP (1974) Manas NP (1990) Nameri NP (1998) Dihing Patkai (2021) Rajiv Gandhi (Orang)(1999) Raimona (2021)	Chakrasila WLS Burachapori WLS (1995) Hollongapar Gibbon WLS Pobitora WLS (1987)	Kaziranga TR, Nameri TR, Manas TR, Orang TR	Deepor Beel
Chhattisgarh	Guru Ghasidas (Sanjay) NP (1981) Indravati (Kutru) NP (1982) Kanger Valley NP (1982)	Achanakmar WLS (1975) Udanti Wild Buffalo WLS Sitanadi WLS Barnawapara WLS Tamor Pingla WLS Badalkhol WLS Semarsot WLS	Achanakmar TR, Udanti-Sitanadi TR, Indravati TR	
Gujarat	Vansda NP (1979) Blackbuck (Velavadar) NP (1976) Gir NP (1975) Marine (Gulf of Kachchh) NP (1982)	Gir WLS (1965) Kutch Desert WLS (1986) Wild Ass WLS (1973)	-	Khijadiya, Nalsarovar, Thol Lake, Wadhvana Wetland

State/Union Territory	National Parks	Wildlife Sanctuaries	Tiger Reserve	Ramsar Site
Himachal Pradesh	Great Himalayan NP (1994) Inderkilla NP (2010) Khirganga NP (2010) Pin Valley NP (1987) Col. Sherjung Simbalbara NP (2010)	Daranghati I & II WLS Shikari Devi WLS Tundah WLS (1962)	-	Chandertal, Pong Dam Lake, Renuka Lake
Jammu and Kashmir	City Forest (Salim Ali) NP (1992) Dachigam NP (1981) Kishtwar NP (1981) Kazinag NP (2000)	Gulmarg WLS Surinsar-Mansar WLS (1990)		Hokera Wetland, Hygam Wetland CSR, Shallbugh Wetland CSR, Surinsar-Mansar Lakes, Wular Lake
Karnataka	Anshi NP (1987) Bandipur NP (1974) Bannerghatta NP (1974) Kudremukh NP (1987) Nagarahole (Rajiv Gandhi) NP (1988)	Bhadra WLS (1974) Dandeli WLS (1987)	Biligiri Ranganatha Temple TR, Dandeli-Anshi (Kali) TR, Nagarahole TR, Bhadra TR, Bandipur TR	Ranganathittu Bird Sanctuary(BS), Ankasamudra Bird CSR, Aghanashini Estuary, Magadi Kere CSR
Kerala	Anamudi Shola NP (2003) Eravikulam NP (1978) Mathikettan Shola NP (2003) Pampadum Shola NP (2003) Periyar NP (1982) Silent Valley NP (1984)	Aralam WLS Neyyar WLS Parambikulam WLS (1973)	Parambikulam TR, Periyar TR	Ashtamudi Wetland, Sasthamkotta Lake, Vembanad-Kol Wetland
Madhya Pradesh	Bandhavgarh NP (1968) Fossil NP (1983) Indira Priyadarshini Pench NP (1975) Kanha NP (1955) Madhav NP (1959) Panna NP (1981) Sanjay NP (1981) Satpura NP (1981) Van Vihar NP (1979)	Bori WLS Pachmarhi WLS (1977) Pench WLS (1975)	Sanjay-Dubri TR, Satpura TR, Bandhavgarh TR, Panna TR, Pench TR, Kanha TR, Veerangana Durgavati TR	Bhoj Wetland, Sakhya Sagar, Sirpur Lake, Yashwant Sagar
Maharashtra	Chandoli NP (2004) Gugamal NP (1975) Navegaon NP (1975) Pench (Jawaharlal Nehru) NP (1975) Sanjay Gandhi (Borivali) NP (1983) Tadoba NP (1955)	Bhimashankar WLS Chaprala WLS Karnala BS Nandur Madhmeshwar WLS (1986) Lonar Lake WLS (2000)	Navegaon-Nagzira TR, Sahyadri TR, Pench TR, Tadoba-Andhari TR, Melghat TR, Bor TR	Lonar Lake, Nandur Madhameshwar, Thane Creek
Odisha	Bhitarkanika NP (1988) Simlipal NP (1980)	Balukhand-Konark WLS Chilika WLS (1987) Gahirmatha WLS	Satkosia TR, Similipal TR	Ansupa Lake, Bhitarkanika Mangroves, Chilika Lake, Hirakud Reservoir, Satkosia Gorge, Tampara Lake

State/Union Territory	National Parks	Wildlife Sanctuaries	Tiger Reserve	Ramsar Site
Rajasthan	Mukundra Hills NP (2006) Desert NP (1992) Keoladeo Ghana NP (1981) Ranthambore NP (1980) Sariska NP (1992)	Kumbhalgarh WLS Mount Abu WLS Phulwari WLS	Mukandra Hills TR, Sariska TR, Ranthambore TR, Ramgarh Vishdhari TR	Keoladeo National Park, Sambhar Lake
Tamil Nadu	Guindy NP (1976) Gulf of Mannar Marine NP (1980) Indira Gandhi (Annamalai) NP (1989) Mudumalai NP (1990) Mukurthi NP (1990)		Srivilliputhur Megamalai TR, Sathyamangalam TR, Anamalai TR, Mudumalai TR, Kalakad-Mundan-thurai TR	Chitrangudi BS, Gulf of Mannar Marine Biosphere Reserve, Kanjirankulam BS, Karaivetti BS, Karikili BS, Koonthankulam BS, Longwood Shola Reserve Forest, Pallikarnai Marsh Reserve Forest, Pichavaram Man-grove, Point Calimere Wild-life and BS, Suchindram Theroor Wetland Complex, Udhayamarthanda-puram BS, Vadavur BS, Vedanthangal BS, Vellode BS, Vembannur Wetland Complex
Uttar Pradesh	Dudhwa NP (1977)		Ranipur TR, Dudhwa TR, Pilibhit TR	Bakhira Sanctuary, Haiderpur Wetland, Nawabganj BS, Parvati Arga BS, Saman BS, Samaspur BS, Sandi BS, Sarsai Nawar Jheel, Sur Sarovar, Upper Ganga River
Uttarakhand	Corbett NP (1936) Gangotri NP (1989) Govind NP (1990) Nanda Devi NP (1982) Rajaji NP (1983) Valley of Flowers NP (1982)		Corbett TR, Rajaji TR	Asan Barrage
West Bengal	Buxa NP (1992) Gorumara NP (1992) Jaldapara NP (2014) Neora Valley NP (1986) Singalila NP (1986) Sundarbans NP (1984)		Buxa TR, Sunderbans TR	East Kolkata Wetlands, Sundarban Wetland

State/Union Territory	National Parks	Wildlife Sanctuaries	Tiger Reserve	Ramsar Site
Punjab				Beas CSR, Harike Wetland, Kanjli Wetland, Keshopur-Miani CMR, Nangal Wildlife Sanctuary, Ropar Wetland
Goa	Mollem NP (1992)	Bondla WLS Mhadei WLS (1999)	-	Nanda Lake
Manipur	Keibul-Lamjao NP (1977)	Bunning (1997)	-	Loktak Lake
Meghalaya	Balphakram NP (1986) Nokrek Ridge NP (1997)	Siju WLS Nongkhyllem WLS	-	
Mizoram	Murlen NP (2003) Phawngpui Blue Mountain NP (1997)	Khawnglung WLS Thorangtlang WLS	Dampa TR	Pala Wetland
Telangana	Kasu Brahmananda Reddy NP (1994) Mahavir Harina Vanasthali NP (1994) Mrugavani NP (1994)		Amrabad TR, Kawal TR	
Tripura	Clouded Leopard NP (2007) Bison (Rajbari) NP (2007)	Sepahijala WLS (1987)	-	Rudrasagar Lake
Jharkhand	Betla NP (1986)	Hazaribagh WLS (1976) Dalma WLS Lawalong WLS Topchanchi WLS Parasnath WLS	Palamau TR	
Haryana	Kalesar NP (2003) Sultanpur NP (1989)		-	Sultanpur NP, Bhindawas WLS
Arunachal Pradesh	Mouling NP (1986) Namdapha NP (1983)	Pakhui WLS Mehao WLS	Kamlang TR, Pakke TR, Namdapha TR	
Ladakh Hemis NP (1981)				Tso Kar, Tsomoriri Lake
Sikkim	Khangchendzonga NP (1977)			
Bihar	Valmiki NP (1989)	Valmiki WLS (1978)	Valmiki TR	Kanwar Lake
Nagaland	Intanki NP (1993)		-	

2. Elephant Reserves in India

Zone	State	Elephant Reserves
Periyar-Agasthyamalai Landscape	Kerala	Periyar Elephant Reserve
	Tamil Nadu	Srivilliputhur Elephant Reserve
Brahmagiri-Nilgiri-Eastern Ghats Landscape	Karnataka	Mysore Elephant Reserve
	Kerala	Wayanad Elephant Reserve
		Nilambur Elephant Reserve
	Tamil Nadu	Coimbatore Elephant Reserve
		Nilgiri Elephant Reserve

Zone	State	Elephant Reserves
Meghalaya Landscape	Meghalaya	Garo Hills Elephant Reserve
North Bengal-Greater Manas Landscape	Assam	Chirang-Ripu Elephant Reserve
	West Bengal	Eastern Dooars Elephant Reserve
Kaziranga-Karbi Anglong-Intanki Landscape	Assam	Kaziranga-Karbi Anglong Elephant Reserve
		Dhansiri-Lungding Elephant Reserve
	Nagaland	Intanki Elephant Reserve
Eastern-South Bank Landscape	Assam	Dihing-Patkai Elephant Reserve
	Arunachal Pradesh	South Arunachal Elephant Reserve
Kameng-Sonitpur Landscape	Arunachal Pradesh	Kameng Elephant Reserve
	Assam	Sonitpur Elephant Reserve
East-Central Landscape	Odisha	Mayurbhanj Elephant Reserve
		Mahanadi Elephant Reserve
		Sambalpur Elephant Reserve
	Chhattisgarh	Lemru Elephant Reserve
		Badalkhol – Tamor Pingla Elephant Reserve
North-Western Landscape	Uttrakhand	Shivalik Elephant Reserve
	Uttar Pradesh	Uttar Pradesh Elephant Reserve

3. Biosphere Reserve In India

NOTE: * denotes that Biosphere Reserve is included in UNESCO Man & Biosphere Reserve Programme

Name (Year)	Location and State	Key Fauna and Other Info
Nilgiri Biosphere Reserve* (1986)	Part of Wayanad, Nagarhole, Bandipur and Mudumalai, Nilambur, Silent Valley (Karnataka, Tamil Nadu and Kerala)	**Key Fauna:** Nilgiri tahr, tiger, lion-tailed macaque **Info:** River Bhavani, Moyar, Kabini (tributaries of Cauvery), Chaliyar, Punampuzha, etc. Forms an almost complete ring around Nilgiri Plateau - Dodabetta peak is the highest in the Nilgiri range Highest waterfall: Kolakambai Fall - Cholanaikans: Only surviving hunter-gatherers of the Indian subcontinent - Kanikaran, the most prominent tribal group UNESCO World Heritage Site since 2012. As it is part of Western Ghats
Nanda Devi Biosphere Reserve* (1988)	Encompasses Nanda Devi and Valley of Flowers National Parks, Parts of Chamoli District, Pithoragarh District & Bageshwar District (Uttarakhand)	Snow leopard, Himalayan black bear UNESCO World Heritage Site, recognized for its outstanding natural beauty and conservation of wild flora and fauna Home to the Bhotia tribe, known for their traditional woolen crafts Rich in high-altitude flora and fauna, including several endangered species like the snow leopard.
Nokrek Biosphere Reserve* (1988)	In West Garo Hills (Meghalaya)	Red panda Dominated by hilly terrain with red loam soil - Home to the Garo tribe, known for their matrilineal society Close to Balpakram National Park, known for its unique geological formations and wild buffalo populations Contains the Siju Cave, famous for its bat population - Plays a crucial role in the conservation of the red panda and other endemic species.

Name (Year)	Location and State	Key Fauna and Other Info
Gulf of Mannar Biosphere Reserve* (1989)	Indian part of Gulf of Mannar extending from Rameswaram island in the north to Kanyakumari in the south of Tamil Nadu and Sri Lanka (Tamil Nadu)	Dugong Encompasses a chain of 21 islands and adjacent coral reefs Notable for the conservation of marine biodiversity, including the endangered Dugong Historical importance for pearl fishing, dating back over 2000 years Local communities include the Marakeyars, primarily engaged in fishing India's first marine biosphere reserve, playing a critical role in marine conservation efforts.
Sundarbans Biosphere Reserve* (1989)	Part of the delta of the Ganges and Brahmaputra river system (West Bengal)	Royal Bengal tiger World's largest mangrove forest, critical for protecting the Bengal tiger UNESCO World Heritage Site, noted for its unique ecosystem and biodiversity Supports a wide range of fauna, including several endangered species like the estuarine crocodile and the Gangetic dolphin The area is also known for its role in carbon sequestration and its protection against erosion and natural disasters.
Manas Biosphere Reserve (1989)	Part of Kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamrup and Darrang Districts (Assam)	Asiatic elephant, tiger, Assam roofed turtle, hispid hare, golden langur, pygmy hog UNESCO World Heritage Site, recognized for its rich biodiversity and unique landscape Important habitat for the Bengal Florican and the wild water buffalo Includes the Manas National Park, known for its efforts in the conservation of the tiger and the elephant The area is culturally significant, with diverse ethnic groups including the Bodo community.
Great Nicobar Biosphere Reserve* (1989)	Southernmost of the Andaman and Nicobar Islands (Andaman and Nicobar Islands)	Saltwater crocodile Encompasses unique island ecosystems with dense tropical forests Home to indigenous Nicobarese and Shompen tribes, living in harmony with nature - Important for the conservation of sea turtles and the saltwater crocodile Features Mount Thuillier, the highest point in the Nicobar Islands The area plays a crucial role in studying island biodiversity and conservation strategies.
Simlipal Biosphere Reserve* (1994)	Part of Mayurbhanj district (Odisha)	Gaur, royal Bengal tiger, Asian elephant Named after the abundance of Semul (red silk cotton trees) in the area Features waterfalls, such as Barehipani and Joranda, and high peaks Important for elephant conservation and a tiger reserve under Project Tiger Rich in tribal culture, with several communities living in and around the reserve The area is noted for its efforts in conserving biodiversity and promoting ecotourism.

Name (Year)	Location and State	Key Fauna and Other Info
Dihang-Dibang Biosphere Reserve (1998)	Part of Siang and Dibang Valley (Arunachal Pradesh)	Mishmi takin, musk deer Encompasses parts of the Eastern Himalayas with significant elevation variations Home to the Mishmi, Idu, and Adi tribes, known for their rich cultural heritage Important for the conservation of the Mishmi takin and other endemic species The area is characterized by its rugged terrain and rich biodiversity, including several species of rhododendron.
Dibru-Saikhowa Biosphere Reserve (1997)	Part of Dibrugarh and Tinsukia districts (Assam)	White-winged wood duck, water buffalo, black-breasted parrotbill, tiger, capped langur Known for its significant population of the endangered white-winged wood duck - Features a mix of wetlands, grasslands, and forests, providing diverse habitats for wildlife Important area for avian fauna, supporting several rare and endangered bird species The reserve plays a key role in flood mitigation and supports the livelihoods of local communities through fishing and agriculture.
Pachmarhi Biosphere Reserve* (1999)	Parts of Betul District, Hoshangabad District and Chhindwara District (Madhya Pradesh)	Giant squirrel, flying squirrel Known for its rich biodiversity and the Satpura National Park - Features high peaks, deep valleys, and extensive forest cover Significant for the conservation of medicinal plants and traditional knowledge - The area is culturally important, with several archaeological sites of ancient cave paintings
Khangchend-zonga biosphere reserve* (2000)	Parts of Kangchenjunga (Sikkim)	Snow leopard, red panda UNESCO World Heritage Site for its unique diversity of plains, valleys, lakes, glaciers, and spectacular, snow-clad peaks including the third highest peak in the world, Mount Kangchenjunga - Rich in cultural and religious significance, with many sacred lakes, mountains, and monasteries within the park Important habitat for many endemic and threatened species, including the snow leopard and red panda.
Agasthyamalai Biosphere Reserve* (2001)	Neyyar, Peppara and Shenduruny Wildlife Sanctuary and their adjoining areas (Kerala, Tamil Nadu)	Nilgiri tahr, Asian elephant Named after the Agasthyakoodam Peak, which is revered and considered sacred - Encompasses unique ecosystems and endemic species, playing a crucial role in the conservation of Western Ghats biodiversity - The region is rich in medicinal plants and supports traditional healthcare practices of tribal communities Efforts are focused on preserving the unique flora and fauna and promoting sustainable livelihoods.

Name (Year)	Location and State	Key Fauna and Other Info
Achanakmar-Amarkantak Biosphere Reserve* (2005)	Part of Anuppur, Dindori and Bilaspur districts (Madhya Pradesh, Chhattisgarh)	Four-horned antelope, Indian wild dog, sarus crane, white-rumped vulture, sacred grove bush frog Serves as a critical catchment area for the Narmada and the Son rivers, providing significant ecosystem services Rich in biodiversity, including many medicinal plants and traditional crops The area is significant for cultural and spiritual reasons, with many pilgrimage sites - Conservation efforts focus on preserving the unique landscape and biodiversity, while supporting sustainable development.
Great Rann of Kutch Biosphere Reserve (2008)	Part of Kutch, Morbi, Surendranagar and Patan districts (Gujarat)	Indian wild ass Known for the seasonal salt marshes, one of the largest salt deserts in the world Important habitat for the endangered Indian wild ass and many migratory birds The region is culturally rich, with unique traditions, crafts, and architecture Conservation efforts aim to balance biodiversity preservation with the sustainable development of local communities.
Cold Desert Biosphere Reserve (2009)	Pin Valley National Park and surroundings; Chandratal and Sarchu & Kibber Wildlife Sanctuary (Himachal Pradesh)	Snow leopard Characterized by high altitude ecosystems, including valleys, mountains, and cold deserts - Important for the conservation of the snow leopard and Himalayan ibex The area supports unique high-altitude flora and fauna, adapted to the cold desert conditions Local communities, such as the Spiti tribe, have traditional lifestyles closely linked with the natural environment.
Seshachalam Hills Biosphere Reserve (2010)	Seshachalam Hill Ranges covering parts of Chittoor and Kadapa districts (Andhra Pradesh)	Slender loris Encompasses the Tirumala hills, known for the famous Venkateswara Temple Rich in biodiversity, including several endemic species of flora and fauna The area is important for the conservation of the red sanders tree, highly valued for its timber Conservation efforts focus on preserving the unique ecosystems and promoting sustainable use of resources.
Panna Biosphere Reserve* (2011)	Part of Panna and Chhattarpur districts in Madhya Pradesh (Madhya Pradesh)	Bengal tiger, Chinkara, Nilgai, Sambhar sambar deer, and Sloth bear Features the Panna National Park, known for its successful tiger reintroduction program Rich in water resources, including the Ken River, supporting diverse wildlife The area combines significant geological features, including waterfalls and caves with prehistoric paintings Efforts in conservation and community engagement have been pivotal in the reserve's success in wildlife preservation.

4. Major Ramsar Sites in India

Ramsar Site (State/UT)	Year	Key Notes
Chilika Lake (Odisha)	1981	World's second-largest coastal lagoon and India's largest lagoon. Delisted from Montreux Records in 2002 after rehabilitation efforts. Located at the mouth of the Daya River. First Ramsar Site in India. - Hosts rare Irrawaddy dolphin species. Top attractions: Nalabana Bird Sanctuary, Kalijai temple, Beacon Island.
Keoladeo National Park (Rajasthan)	1981	Popular avifauna sanctuary in Bharatpur district. Placed under Montreux Record due to water shortage danger and invasive grass growth. - Famous for migratory Siberian Crane.
Wular Lake (Jammu & Kashmir)	1990	Largest freshwater lake in India. Known for floating vegetation like Water Chestnut. Contributes to government revenue through the fishing industry and paddy cultivation.
Sambhar Lake (Rajasthan)	1990	Largest inland saline lake in India. Important wintering region for migratory birds like flamingos. - Geological significance in providing evidence of the Tethys Sea.
Loktak Lake (Manipur)	1990	Largest freshwater lake in northeastern India. Placed under Montreux Record. Hosts Keibul Lamjao National Park, the world's only floating national park. Home to the Sangai Deer, or Dancing Deer.
Harike Wetlands (Punjab)	1990	Largest wetland in northern India. Shallow water reservoir with 13 islands. - Located near the confluence of Beas and Satluj rivers. Breeding zone for various species of Anatidae.
Ashtamudi Wetland (Kerala)	2002	Large palm-shaped natural backwater wetland. Forms estuary with sea at Neendakara. Popular fishing zone in Kerala. - Known for Karimeen fish.
Bhitarkanika Mangroves (Odisha)	2002	Second largest mangrove ecosystem in India. Known for Olive ridley turtles and Saltwater crocodiles. Located near Brahmani and Baitrani Rivers.
Bhoj Wetland (Madhya Pradesh)	2002	Made of Upper and Lower lakes in Bhopal. Upper lake supports 40% of Bhopal's potable water supply. Home to Sarus Crane, largest bird of India.
Deepor Beel (Assam)	2002	Permanent freshwater lake in former channel of Brahmaputra River. Major stormwater storage basin for Guwahati. Represents Burma Monsoon Forest Biogeographic Region.
East Kolkata Wetlands (West Bengal)	2002	Mixture of natural and man-made wetlands. Treats sewage of Kolkata. - Example of multi-use wetland.
Kanjli Wetland (Punjab)	2002	Created by building a barrage across Bein River. Provides irrigation facilities. Common reptile found: tortoise.
Kolleru Lake (Andhra Pradesh)	2002	Large natural eutrophic lake between Godavari and Krishna river basins. Acts as a natural soaking agent to check floods. Largest shallow lake in Asia.

Ramsar Site (State/UT)	Year	Key Notes
Point Calimere Wildlife and Bird Sanctuary (Tamil Nadu)	2002	Situated along Palk Strait at Point Calimere. Constructed for conservation of Blackbuck Antelope. Known for the congregation of greater flamingos.
Pong Dam Lake (Himachal Pradesh)	2002	Also known as Maharana Pratap Sagar Lake. Constructed by highest embankment dam in India on Beas River. Habitat for Mahseer Angling fish.
Ropar Wetland (Punjab)	2002	Man-made wetland built by barrage diverting water from Satluj River. Breeding place for hog deer, sambar, smooth-coated otter, etc.
Sasthamkotta Lake (Kerala)	2002	Largest freshwater lake in Kerala
India marked **World Wetlands Day 2024** by expanding its Ramsar sites tally to 80 from the existing 75, adding five new wetlands across Karnataka and Tamil Nadu. ❑ **Ankasamudra Bird Conservation Reserve (Karnataka),** ❑ **Aghanashini Estuary (Karnataka),** ❑ **Magadi Kere Conservation Reserve (Karnataka),** ❑ **Karaivetti Bird Sanctuary (Tamil Nadu),** ❑ **Longwood Shola Reserve Forest (Tamil Nadu).**		

5. Major Lakes in India

a) Natural Lakes

Name	State	Info
Wular Lake	Jammu & Kashmir	One of the largest freshwater lakes in Asia, significant for its biodiversity and hydrology.
Loktak Lake	Manipur	Known for its phumdis (floating islands), including the world's only floating national park, Keibul Lamjao.
Chilika Lake	Odisha	Asia's largest brackish water lagoon, famous for its bird sanctuary and Irrawaddy dolphins.
Vembanad Lake	Kerala	India's longest lake and the largest in Kerala, known for the famous Nehru Trophy Boat Race.
Dal Lake	Jammu & Kashmir	Famous for its houseboats and shikara (boat) rides, a major attraction in Srinagar.
Pangong Tso	Ladakh	A high-altitude saline lake situated at an elevation of about 4,350 m (14,270 ft) in the Himalayas. Known for its mesmerizing blue waters that change colors with the sunlight. Extends from India to China and is a popular tourist destination.
Tsomoriri Lake	Ladakh	Located in the Changthang plateau in Ladakh, one of the largest high-altitude lakes in India. A Ramsar Site known for its stunning beauty, diverse wildlife, and remote location, popular among nature enthusiasts and trekkers.
Nainital Lake	Uttarakhand	Situated in the town of Nainital in the Kumaon region, a natural freshwater lake surrounded by lush green hills. A popular tourist destination offering boating and other recreational activities.
Tsongmo Lake (Changu Lake)	Sikkim	A glacial lake located at an altitude of 3,753 m (12,313 ft) in the East Sikkim district, revered by both Buddhists and Hindus. Known for its scenic beauty, especially in winter when it freezes over.
Gurudongmar Lake	Sikkim	One of the highest lakes in the world, situated at an altitude of about 5,430 m (17,800 ft) in North Sikkim. Considered sacred by both Buddhists and Sikhs and is named after Guru Dongmar, a revered figure in Tibetan Buddhism. Surrounded by snow-capped peaks.

Name	State	Info
Pulicat Lake	Tamil Nadu and Andhra Pradesh	Pulicat Lake is the second largest brackish-water lake or lagoon in India, known for its diverse bird sanctuary, which is a haven for migratory birds, including flamingos. It is located on the border of Tamil Nadu and Andhra Pradesh on the Coromandel Coast in South India. The lake encompasses the Pulicat Lake Bird Sanctuary, attracting bird watchers and nature enthusiasts. The area is also significant for its rich biodiversity and its importance to the local fishing communities.
Sambhar Salt Lake	Rajasthan	Although naturally formed, the lake's capacity and structure have been significantly enhanced through the construction of dykes and channels for the purpose of salt production, making it a notable man-made modification.

b) Man Made Lakes

Name State	Info
Bhojtal (Madhya Pradesh)	Also known as Upper Lake, it is one of the largest artificial lakes in India, created by King Bhoj in the 11th century. It serves as a major source of potable water for the city of Bhopal.
Sukhna Lake (Chandigarh)	A reservoir at the foothills of the Himalayas, created in 1958 by damming the Sukhna Choe, a seasonal stream. It is a popular spot for leisure and water sports.
Hussain Sagar (Telangana)	Built by Ibrahim Quli Qutb Shah in 1563, it is a heart-shaped lake that connects the twin cities of Hyderabad and Secunderabad. It is famous for its large monolithic Buddha statue in the middle.
Dhebar Lake (Rajasthan)	Also known as Jaisamand Lake, it was created in the 17th century when Rana Jai Singh of Udaipur built a marble dam across the Gomati river. It is one of the largest artificial lakes in Asia.
Powai Lake (Maharashtra)	Located in Mumbai, it was built by the British in 1890 to augment the city's water supply. However, it is now primarily used for recreation and fishing.
Kodaikanal Lake (Tamil Nadu)	A man-made lake constructed in 1863 by Sir Vere Henry Levinge, the then Collector of Madurai, for recreational purposes. It is situated in Kodaikanal and is a popular tourist attraction.

6. India Adopts SAWEN

India has officially adopted the Statute of the South Asia Wildlife Enforcement Network (SAWEN) with the aim of enhancing collaboration with member countries. SAWEN is dedicated to combating illegal wildlife trade through effective communication, coordination, collaboration, capacity building, and cooperation among its member nations.

Name of the Species	Name of the Zoo
Red Panda & Snow Leopard	Padmaja Naidu Himalayan Zoological Park, Darjeeling
Hoolock Gibbon	Biological Park, Itanagar
Clouded Leopard	Sepahijala Zoological Park, Agartala
Indian Pangolin	Nandankanan Biological Park, Bhubaneswar

Lion-tailed Macaque	Arignar Anna Zoological Park, Chennai
Grey Jungle Fowl	Sri Venkateswara Zoological Park, Tirupati
Dolphin	Vikramshila Gangetic Dolphin Sanctuary, Bhagalpur
Crocodile	Madras Crocodile Bank, Chennai

ANIMAL DIVERSITY IN INDIA

India boasts remarkable biodiversity, including a rich tapestry of animal life. From the majestic Bengal tiger to the elusive snow leopard, and from the playful dolphins of the Ganges to the vibrant birdlife of the Western Ghats, the country is home to a diverse array of wildlife. With its varied ecosystems ranging from the Himalayan mountains to the dense rainforests of the Western Ghats and the vast mangrove forests of the Sundarbans, India harbors a staggering diversity of animal species.

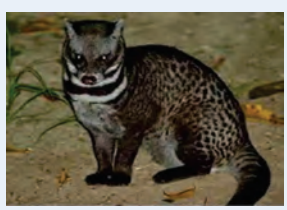
This diversity not only contributes to the ecological health of the region but also holds cultural, economic, and ecological significance. Understanding and conserving the animal diversity of India are essential for maintaining ecosystem balance, preserving natural heritage, and ensuring the well-being of both wildlife and human communities.

1. Conservation Status Categories Defined by IUCN

The International Union for Conservation of Nature (IUCN) classifies species into various categories based on their conservation status. These categories help in understanding the level of threat faced by different species and guide conservation efforts accordingly

A. Critically Endangered Category Fauna

S.No	Name	Habitat	Location	Additional Info
1.	**Great Indian Bustard**	Grasslands and semi-arid regions	Desert National Park (Rajasthan), Kutch Bustard Sanctuary (Gujarat)	Critically endangered due to habitat loss and hunting. Project Great Indian Bustard focuses on its conservation.
2.	**Chinese Pangolin**	Forests, grasslands	Northeast India; particularly in states like Arunachal Pradesh	Threatened by poaching for its scales used in traditional medicine. Mostly nocturnal and solitary.
3.	**Bugun Liocichla**	Dense bamboo and forest undergrowth	Singchung Bugun Village Community Reserve, Arunachal Pradesh	Discovered in 2006; extremely rare with a very small known population.
4.	**Pondicherry Shark**	Coastal and estuarine waters	Reported from the coastal waters of Kerala and West Bengal, but sightings are rare.	Critically endangered, known from only a few specimens.

S.No	Name	Habitat	Location	Additional Info
5.	**Irrawaddy Dolphin**	Freshwater; brackish water near coasts	Chilika Lake (Odisha), Sundarbans (West Bengal)	Known for its bulging forehead and short beak, it faces threats from bycatch and habitat loss.
6.	**Kashmir Stag (Hangul)**	Dense riverine forests	Dachigam National Park (Jammu & Kashmir)	The state animal of Jammu & Kashmir, it is vulnerable due to habitat destruction and overgrazing by domestic livestock.
7.	**Northern River Terrapin**	Brackish water of tidal rivers and estuaries	Sundarbans (West Bengal), Bhitarkanika Mangroves (Odisha)	Critically endangered due to habitat loss, over-exploitation for food, and accidental capture in fishing gear.
8.	**Gharial**	Rivers with fast-flowing water and high sandbanks	Chambal River (National Chambal Sanctuary, Uttar Pradesh, Rajasthan, Madhya Pradesh), Gandak River (Bihar), Ghaghara and Sone rivers.	Critically endangered; conservation efforts include captive breeding and reintroduction projects.
9.	**Ganges Shark**	Riverine environment	Ganga River, Brahmaputra River; presence in national parks and sanctuaries is uncertain due to the rarity of sightings.	Extremely rare, possibly critically endangered. Known for its habitat in the Ganges-Brahmaputra river system.
10.	**Malabar Civet** 	Wooded plains and hill slopes of evergreen rainforests	Western Ghat	Elusive mammal known for its distinctive black fur with white spots. Due to habitat loss and poaching, it is critically endangered, making conservation efforts crucial for its survival.
11.	**Double-humped Camel**	Cold deserts, high altitudes	Ladakh region, Himalayas, Central Asia	Adapted to harsh climates, used as pack animals and for transportation in mountainous terrains.

B. Endangered Category Fauna

S.No	Name	Habitat	Location	Additional Info
1.	**Golden Langur**	Tropical and subtropical forests	Assam (Manas National Park), Bhutan, Tripura	Found in small isolated populations, primarily in Assam. Listed as Endangered due to habitat loss and fragmentation.
2.	**Nilgiri Tahr**	High-altitude grasslands and sholas (tropical montane forests)	Western Ghats, especially in Kerala (Eravikulam National Park)	Endemic to the Western Ghats. Threatened by habitat loss, poaching, and climate change. Protected under Schedule I of the Indian Wildlife (Protection) Act, 1972.
3.	**Indian Pangolin**	Forests, grasslands, and agricultural landscapes	Throughout India	Highly elusive and primarily nocturnal. Threatened by habitat loss and poaching for scales. Protected under Schedule I of the Wildlife Protection Act, 1972.
4.	**Indus Dolphins**	Freshwater rivers and lakes	Indus River (Punjab, India), also found in Pakistan	Blind species like bats, rely on echolocation for navigation. **Listed as Endangered.** Protected under Schedule I of the Wildlife Protection Act, 1972.
5.	**Asiatic Lions**	Dry deciduous forests and scrub forests	Gir Forest National Park and Wildlife Sanctuary (Gujarat)	Endemic to the Gir Forest of Gujarat. Listed as Endangered, with only about 600 individuals left in the wild. Conservation efforts include habitat protection and community-based conservation initiatives.
6.	**Elephant**	Forests, grasslands, and wetlands	Throughout India, particularly in Karnataka, Assam, and Kerala	National Heritage Animal of India. Threatened by habitat loss, human-wildlife conflict, and poaching. Protected under Schedule I of the Wildlife Protection Act, 1972, and listed in Appendix I of CITES.
7.	**Gangetic Dolphins**	Rivers, including freshwater and brackish water	Ganges and Brahmaputra river systems, Vikramshila Gangetic Dolphin Sanctuary (Bihar)	Also known as the Ganges River Dolphin. Among the four freshwater dolphin species in the world. Listed as Endangered due to habitat degradation, pollution, and fishing nets. Protected under Schedule I of the Wildlife Protection Act, 1972.
8.	**Hog Deer or Pada**	Grasslands, swamps, and floodplains	Terai grasslands (along the Himalayan foothills) in states like Uttar Pradesh and Assam, also reported in Keibul Lamjao National Park (Manipur)	Two sub-species: Western and Eastern hog deer. Eastern hog deer is critically endangered. Population decline due to habitat loss, poaching, and human disturbance. Protected under Schedule I of the Wildlife Protection Act, 1972.

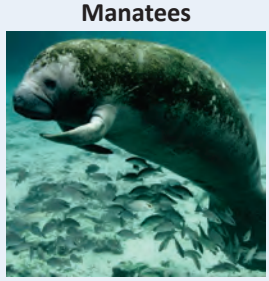
S.No	Name	Habitat	Location	Additional Info
9.	**Red Panda (Lesser Panda)**	Temperate forests with bamboo understories	Eastern Himalayas and southwestern China, found in India's Sikkim, Arunachal Pradesh, and Meghalaya	Distinctive reddish-brown fur and bushy tail. Highly arboreal and primarily solitary. Listed as Endangered due to habitat loss, poaching, and fragmentation. Protected under Schedule I of the Wildlife Protection Act, 1972, and listed in Appendix I of CITES.
10.	**Sangai (Brown Antlered deer)**	Floating marshy grasslands, Phumdis (floating mass of vegetation)	Keibul Lamjao National Park, Loktak Lake (Manipur)	Also known as the Dancing Deer. Found only in Manipur's floating marshy grasslands and wetlands. Listed as Endangered due to habitat loss, poaching, and invasive species. Protected under Schedule I of the Wildlife Protection Act, 1972, and listed in Appendix I of CITES.
11.	**Indian Ocean Humpback Dolphin**	Shallow coastal waters, estuaries, and lagoons	Along the Indian Ocean coast from South Africa to India	Often seen near fishing grounds and human settlements. Vulnerable to entanglement in fishing gear, habitat degradation, and pollution. Protected under Schedule I of the Wildlife Protection Act, 1972.
12.	**Arabian Sea Humpback Whale**	Deep waters of the Arabian Sea	Off the coasts of India, Iran, Iraq, Kuwait, Oman, Pakistan, Sri Lanka, United Arab Emirates, and Yemen	Population status uncertain, facing threats from ship strikes, entanglement in fishing gear, and habitat degradation. Listed as Endangered.
13.	**Tiger**	Forests, grasslands, wetlands	Kanha National Park, Bandhavgarh National Park (India), Sundarbans (India/ Bangladesh)	Top predator, plays a crucial role in ecosystem balance.
14.	**Dhole (Asian Wild Dog)**	Forests, grasslands, and alpine zones	Bandipur National Park, Nagarahole National Park (India), Khao Sok National Park (Thailand)	Highly social animals, live in large packs and are skilled hunters.
15.	**Lion-tailed Macaque**	Tropical rainforests	Silent Valley National Park, Anamalai Tiger Reserve (India)	Endemic to the Western Ghats, known for its silver-white mane.
16.	**Kharai Camel**	Salt marshes, coastal areas	Kutch District, Gujarat	Adapts to saline desert environment, known as 'swimming camel', feeds on mangroves, unique eco-tonal species

C. Vulnerable Category Fauna

S.No	Name	Habitat	Location	Additional Info
1.	**Mugger Crocodile**	Freshwater environments like rivers, lakes, ponds, and marshes	Throughout India, especially in protected areas like National Chambal Sanctuary, Ranganthittu Bird Sanctuary	Listed under Schedule I of the Wildlife Protection Act, 1972. Faces threats from habitat destruction, entanglement in fishing nets, and pollution.
2.	**Sarus Crane**	Wetlands, marshes, and agricultural fields	Uttar Pradesh (state bird), also found in Rajasthan, Gujarat, and other parts of Northern India	The world's tallest flying bird. Vulnerable due to habitat loss, human disturbance, and agricultural expansion.
3.	**Olive Ridley Turtle**	Tropical and subtropical waters of the Indian and Pacific Oceans	Odisha's Gahirmatha Beach, Rushikulya Rookery, and the mouth of the Devi River are major nesting sites	Known for their arribada, where thousands come ashore to nest. Threatened by egg collection, fishing nets, and plastic pollution.
4.	**Snow Leopard**	Alpine and subalpine zones at elevations from 3,000 to 4,500 meters	Himalayan regions of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh	Endangered species protected under Schedule I of the WPA, 1972. Threats include poaching, prey depletion, and habitat fragmentation.
5.	**Aldabra Giant Tortoise**	Aldabra Atoll in the Seychelles	Not naturally found in India, but introduced populations exist in zoos and wildlife parks	One of the largest tortoise species, known for its long lifespan. Threatened by habitat loss and introduced predators on its native islands.
6.	**African Cheetah**	Open savannas and arid grasslands	Historically found in India, reintroduction plans are underway in Kuno National Park, Madhya Pradesh	Extinct in India since the 20th century, efforts are being made for its reintroduction. The species faces threats from habitat loss and conflicts with humans.
7.	**Great One-Horned Rhinoceros**	Grasslands and adjacent riverine forests	Kaziranga and Manas National Parks in Assam, Pobitora Wildlife Sanctuary, Orang National Park	Vulnerable species due to poaching for its horn and habitat loss. Protected under Schedule I of the Wildlife Protection Act.
8.	**Indian Leopard**	Forests, grasslands, savannas, and mangroves	Widely distributed across Indian subcontinent including national parks and wildlife sanctuaries	Schedule I species under WPA, 1972. Faces threats from habitat loss, poaching, and conflict with humans.

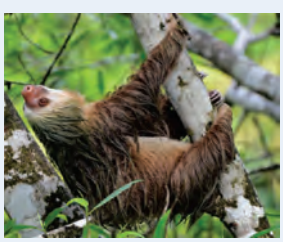
S.No	Name	Habitat	Location	Additional Info
9.	**Black Panther**	Dense forest and tropical rainforest	Karnataka (Bhadra, Dandeli-Anshi), Kerala (Periyar), Odisha (Sundergarh), Maharashtra (Satara)	Melanistic variant of leopards or jaguars, protected under Schedule I of WPA, 1972. Rare and elusive, threatened by habitat loss and human-wildlife conflict.
10.	**Great Indian Hornbill**	Tropical and subtropical forests	Western Ghats and Northeast India; Periyar Wildlife Sanctuary, Anamalai Tiger Reserve, Namdapha National Park	Known for its large size and vibrant bill, this species plays a crucial role in forest ecology as a seed disperser.

2. Marine Mammals

Name	Habitat / Distribution	Additional Info
Freshwater/River Dolphin	India, Bangladesh, Nepal, Pakistan	**Includes two subspecies:** the Ganges river dolphin and the Indus river dolphin.
Ganges River Dolphin	Ganges and Brahmaputra Rivers, and their tributaries in Bangladesh, India, Nepal	**IUCN : Endangered** Recognized as the **National Aquatic Animal of India.**
Indus River Dolphin	Indus River in Pakistan, and its Beas and Sutlej tributaries	**IUCN : Endangered** Indus river dolphins, like their Ganges counterparts, serve as significant indicators of river ecosystem health.
Dugong	Found in over 30 countries; in India, observed in the Gulf of Mannar, Gulf of Kutch, Palk Bay, and the Andaman and Nicobar Islands.	**IUCN : Vulnerable** Threatened by hunting, habitat degradation, and fishing-related fatalities.
Manatees 	Caribbean Sea, Gulf of Mexico, the Amazon Basin, and West Africa	**IUCN : Vulnerable** Threatened by coastal development, red tide, and hunting.

3. Egg-Laying Mammals (Monotremes)

Monotremes represent a unique subgroup of mammals distinguished by their reproductive process, which involves laying eggs rather than giving birth to live young. There are only five existing species within this category: the duck-billed platypus and four species of echidnas, also known as spiny anteaters. These species are exclusively found in Australia and New Guinea.

Category	Species/Group	Habitat/Distribution and Key Characteristics
Monotremes	**Echidnas (Spiny Anteaters)**	Australia and New Guinea: Carry eggs in a pouch until hatching. Newborns attach to the mammary gland for nourishment.
Monotremes	**Platypus**	Eastern Australia, including Tasmania: Female lays eggs in burrows lined with leaves. Male has venom capable of causing severe pain or death to small animals.
Marsupials	**General Marsupials**	Various, including Australia and Americas: Give birth to embryonic offspring that climb to the pouch for further development. Shorter gestation due to yolk-type placenta.
Placental Mammals	**General Placental Mammals** 	Worldwide: Develop in the uterus with placental connection to mother. Longer gestation periods, more developed at birth.

4. Marsupials: Unique Reproductive Adaptations

Marsupials: Unique Reproductive Adaptations Marsupials, often associated with pouched mammals like the kangaroo, wallaby, and koala, exhibit distinct reproductive characteristics compared to placental mammals.

Features	Description
Pouched Reproduction	Marsupial mammals possess a placenta, albeit short-lived and offering limited fetal nourishment. They give birth prematurely, with the offspring, essentially helpless embryos, making their way from the mother's birth canal to the nipples. **Examples** include the kangaroo and wallaby, where the extremely underdeveloped newborn must navigate to the pouch for continued development.
Pouch Nourishment	Upon reaching the pouch, the young marsupial latches onto a nipple and continues its development over weeks or months, depending on the species. This method of pouch-based nourishment contrasts with the in-utero nourishment provided by placental mammals' longer gestation periods. The koala is another example, nurturing its young in its pouch where the developing joey receives milk and, eventually, pre-digested eucalyptus leaves.

Yolk-Type Placenta	The short gestation period characteristic of marsupials is attributed to their yolk-type placenta, a less complex structure compared to the placenta of placental mammals. This adaptation is evident in species like the sugar glider, a small marsupial that completes much of its development post-birth within the safety of the maternal pouch.
Extinction and Evolution	Marsupials like the Tasmanian tiger (also known as the thylacine) and the marsupial wolf have gone extinct, marking shifts in the evolutionary landscape. These extinctions highlight the unique evolutionary path of marsupials and the environmental pressures they face.

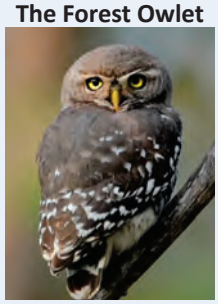
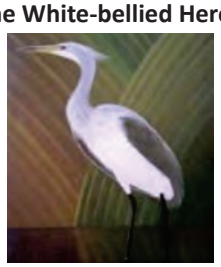
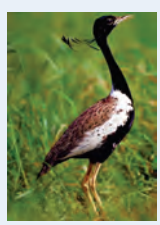
5. Placental Mammals

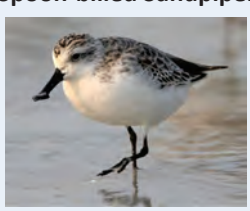
In-Utero Nourishment In contrast, placental mammals nourish their live young in the mother's uterus through a specialized organ known as the placenta. This structure facilitates a direct exchange of nutrients between the mother's blood supply and the developing embryo, enabling longer gestation periods and more advanced development at birth.

Examples of placental mammals include humans, elephants, and whales, all of which support their young through a complex placenta that ensures the fetus is well-nourished and protected until a more advanced stage of development is reached at birth.

6. Birds

A. Critically Endangered Category Birds

Name	Habitat	Feature	Distribution	Threats
Jerdon's Courser	Undisturbed scrub jungle with open areas	Nocturnal bird endemic to northern Andhra Pradesh, India. Flagship species for threatened scrub jungle. Rediscovered in 1986 after being presumed extinct.	Northern Andhra Pradesh, India	Clearing scrub jungle, creation of pastures, illegal trapping, habitat degradation, quarrying.
The Forest Owlet 	Dry deciduous forest	Rediscovered in 1997 after more than a century of absence. Endemic to South and North-West Maharashtra, India. Habitat loss due to logging, tree cutting.	South and North-West Maharashtra, India	Logging operations, burning and cutting of trees, habitat destruction.
The White-bellied Heron 	Rivers with sand/gravel bars, inland lakes	Extremely rare bird found in Assam, Arunachal Pradesh, Bhutan, and Myanmar. Habitat loss due to degradation of lowland forests and wetlands.	Assam, Arunachal Pradesh, Bhutan, Myanmar, Bangladesh	Loss and degradation of lowland forests and wetlands due to human activities.
The Bengal Florican 	Grasslands interspersed with scrublands	Rare bustard species known for elaborate mating dance. Endemic to Cambodia, India, and Nepal. Grassland habitat conversion for agriculture, human activities.	India (Uttar Pradesh, Assam, Arunachal Pradesh), Cambodia, Nepal	Habitat conversion for agriculture, population decline due to human activities.

Name	Habitat	Feature	Distribution	Threats
The Himalayan Quail	Tall grass and scrub on steep hillsides	Presumed extinct since 1876, possible sightings reported. Native to Western Himalayas, India. Reluctance to fly and preference for dense grass habitats make detection challenging.	Western Himalayas, India	Indiscriminate hunting during colonial period, habitat modification.
Pink-headed Duck	Overgrown still-water pools, marshes, swamps	Not conclusively recorded in India since 1949. Deep pink head and neck in males. Found in India, Bangladesh, Myanmar. Wetland degradation, hunting.	India, Bangladesh, Myanmar	Wetland degradation, habitat loss, hunting.
Sociable Lapwing	Fallow fields, scrub desert	Critically endangered winter migrant to India. Rapid population decline due to habitat loss and hunting.	Central Asia, Asia Minor, Russia, Egypt, India, Pakistan	Habitat conversion to arable land, illegal hunting, human settlements.
Spoon-billed Sandpiper 	Coastal areas with sparse vegetation	Scarce population due to specialized breeding habitat. Found in Indian coastal areas. Habitat degradation, land reclamation, human disturbance.	West Bengal, Orissa, Kerala, Tamil Nadu, India	Habitat degradation, land reclamation, human disturbance.
Siberian Crane	Wetland areas	Majestic migratory bird winters at Keoladeo National Park, Rajasthan, India. Last documented sighting in 2002.	Keoladeo National Park, Rajasthan, India	Pesticide pollution, wetland drainage, habitat destruction, hunting.

Bird Migration

Migration in birds is a systematic, repeated movement that occurs seasonally, taking them from one location to another. These migrations can cover distances ranging from a few kilometers to several thousands. After a certain period, the birds return to their original starting point.

❑ **Motivations for Migration:**

- **Evading Harsh Conditions:** Migration allows birds to escape extreme weather conditions.
- **Seeking Food Resources:** Birds migrate to areas where food is more plentiful, addressing shortages where they currently reside.
- **Finding Water:** They move to regions where water is readily available, overcoming local scarcities.
- **Optimal Breeding Environments:** Migrating to areas that offer superior conditions for breeding.
- **Reduced Nesting Competition:** Migration helps in finding locations with less competition for securing safe spots for nesting.

B. Winter Migratory Birds

Name	Source	Destination
Siberian Cranes	Siberia, Russia	Rajasthan, India
Greater Flamingo	Iran, Central Asia	Various parts of India
Amur Falcon	Southeastern Siberia, Northern China	Northeast India
Bar-headed Goose	Tibet, Central Asia	Wetlands across India
Black-necked Crane	Tibetan Plateau	Arunachal Pradesh, India
Demoiselle Crane	Central Eurasia	Rajasthan, India
Eurasian Wigeon	Northern Europe, Asia	Wetlands across India
Northern Pintail	Northern Europe, Asia, North America	Wetlands across India
Ruddy Shelduck	Southeast Europe, Central Asia	Northwest India
Common Teal	Northern Europe, Asia	Across India
Green Sandpiper	Europe, Asian parts of Russia	Across India
Spotted Redshank	Northern Europe, Siberia	Coastal and inland wetlands in India

C. Summer Migratory Birds

Name	Source Region	Destination in India
White-throated Kingfisher	Widespread across Asia	Throughout India
Purple Sunbird	South Asia, Southeast Asia	Throughout India
Forest Wagtail	Southeast Asia, Northeast India	South and Northeast India
Asian Koel	South Asia, Southeast Asia	Throughout India
Black-crowned Night Heron	Worldwide in warm climates	Wetlands across India
Indian Pitta	South Asia	Central and Southern India
Eurasian Golden Oriole	Europe, Western Asia	Northern and Central India
Blue-cheeked Bee-eater	Northern Africa, Southwestern Asia	Northwest and Central India
Cuckoos (Various species)	Africa, South Asia	Throughout India
Baya Weaver	South Asia	Throughout India

7. Wildlife Diseases

Animal/Wildlife Disease	Pathogen/Transmitter	Susceptible Animals
Chronic Wasting Disease (CWD)	Misfolded prion protein	Deer, elk, moose, reindeer
White-Nose Syndrome	Pseudogymnoascus destructans fungus	Bats (various species)
Avian Influenza (Bird Flu)	Influenza A virus (various strains)	Wild birds, poultry, other mammals
African Swine Fever	African Swine Fever Virus	Domestic pigs, wild boars
Batrachochytrium salamandrivorans (Bsal)	Fungus	Salamanders, newts
Tasmanian Devil Facial Tumor Disease	Tasmanian devil facial tumor virus	Tasmanian devils
Ranavirus	Ranavirus	Amphibians, reptiles, fish
Chytridiomycosis	Batrachochytrium dendrobatidis fungus	Amphibians (frogs, salamanders)
Canine Distemper	Canine Distemper Virus	Dogs, wild canids, raccoons
White-Legged Shrimp Disease	White Spot Syndrome Virus	Shrimp

Rabbit Hemorrhagic Disease Virus 2 (RHDV2)	Lagovirus	Rabbits (wild and domestic)
Rabies	Rabies virus	Tiger, Lion, Bear, Mongoose, Squirrel
Anthrax	Bacillus anthracis	Gaur, Chital, Wild Pig, Barking Deer
Trypanosomiasis	Trypanosoma virus	Tiger, Elephant, Sambar, Macaque
Tuberculosis	Mycobacterium spp.	Deer, Cat, Primates, Elephant
Toxoplasmosis	Toxoplasma gondii	Rhesus Macaque, Civet Cat
Rinderpest	Morbillivirus	Deer, Wild Pig, Wild Buffalo
Foot and Mouth Disease	FMD virus	Gaur, Nilgai, Chital, Sambar, Yak, Mithun
Toxoplasmosis	Toxoplasma gondii	Rhesus Macaque, Civet Cat
West Nile Virus	Flavivirus	Birds, Horses, Humans

PLANT DIVERSITY OF INDIA

India, with its vast and varied geography, hosts an incredible diversity of plant life, making it one of the 17 megadiverse countries in the world.

- The country's flora encompasses a wide range of ecosystems, from the high-altitude Himalayan ranges in the north to the tropical rainforests of the Western Ghats and the northeastern regions, the desert landscapes of Rajasthan in the west, and the coastal and marine ecosystems along its vast coastline.
- India's flora includes more than 45,000 plant species, which account for about 7% of the world's flora. The country has made significant efforts to conserve its biodiversity through the establishment of national parks, wildlife sanctuaries, biosphere reserves, and botanical gardens.
- India's rich plant diversity is not only ecologically significant but also sustains the livelihoods of millions through agriculture, forestry, horticulture, and medicine.
- The traditional knowledge associated with the use of plants for medicinal purposes is vast, particularly in Ayurveda, Unani, Siddha, and local tribal practices. The conservation of India's plant diversity is crucial for ecological balance, environmental sustainability, and cultural heritage.
- India boasts a diverse vegetation due to its wide range of climatic conditions, spanning from torrid to arctic. Few countries of comparable size possess such richness. The country can be categorized into eight distinct floristic regions.

A. 8 Floristic (Botanical) Divisions of India

Region	Location	Climate	Characteristic Vegetation
Western Himalayas	Kashmir to Kumaon	Varies with altitude (Subtropical, temperate, alpine)	Conifers, oaks, rhododendrons, birches, junipers
Eastern Himalayas	Sikkim, Darjeeling, Arunachal Pradesh, parts of Assam & West Bengal	Lush & humid (high rainfall)	Tropical, Subtropical, temperate forests (oaks, laurels, maples, rhododendrons, bamboos)
Assam	Brahmaputra & Surma valleys	Tropical (heavy rainfall)	Evergreen forests, bamboos, tall grasses
Indus Plain	Punjab, Western Rajasthan, Northern Gujarat, parts of Pakistan	Hot, dry, arid	Thorny shrubs, xerophytic plants
Gangetic Plain	Uttar Pradesh, Bihar, West Bengal	Varies (mostly suitable for cultivation)	Remnants of natural forests, heavily modified by agriculture
Deccan Region	Peninsular India	Diverse	Mix of dry deciduous, moist deciduous, scrub forests (teak, Sal, Sandalwood)
Malabar (Western Ghats)	Western coast of India	Heavy rainfall	Tropical rainforests (endemic species)
Andaman and Nicobar Islands	Bay of Bengal	Tropical & humid	Dense evergreen forests, coastal mangroves, unique island flora

B. Plant Classification

Plant classification categorizes plants into various groups based on their structural characteristics and growth patterns, aiding in the understanding of the diversity and relationships among plant species.

Classification	Description	Examples
Herbs	Small, green, tender plants with non-woody stems, typically up to 1 meter tall.	Basil, mint, parsley
Shrubs	Woody perennials with persistent stems, branching from the base, usually up to 6 meters tall.	Lilac, azalea, rose
Trees	Large woody perennials with a single main stem (trunk) and a distinct crown, generally taller than shrubs.	Oak, maple, pine
Parasites	Organisms deriving nutrition from other living plants (hosts) using haustoria.	
	1) Total Parasites: Depend entirely on the host for nourishment.	Dodder (Cuscuta), broomrape (Orobanche)
	2)Partial Parasites: Obtain part of their nourishment from the host, but also have some ability to photosynthesize.	Indian paintbrush (Castilleja), mistletoe
Epiphytes	Plants that grow on other plants for physical support only, absorbing moisture and nutrients from the air and rainwater.	Orchids, bromeliads, Spanish moss
Climbers	Plants that climb up support using tendrils, hooks, aerial roots, or by twining around them.	Grapevines, ivy, morning glories

C. Common Leguminous Plants

Common Name	Scientific Name	Features
Pea	Pisum sativum	Climbing vine with green pods containing edible seeds.
Bean	Phaseolus vulgaris	Erect bush or climbing vine with various colored pods containing edible seeds.
Lentil	Lens culinaris	Annual plant with small, lens-shaped seeds used in soups and stews.
Chickpea	Cicer arietinum	Bushy plant with round, beige seeds, a staple food in many cultures.
Peanut	Arachis hypogaea	Groundcover plant with nuts growing underground, also known as groundnut.
Soybean	Glycine max	Tall plant with pods containing oil-rich seeds used for food and industrial purposes.
Alfalfa	Medicago sativa	Important forage crop for livestock, with trifoliate leaves and purple flowers.
Clover	Trifolium spp.	Low-growing plants with trifoliate leaves, commonly used as cover crops and pasture forage.
Lupin	Lupinus spp.	Diverse group with various flower colors, cultivated for ornament, food, and soil improvement.
Acacia	Acacia spp.	Trees or shrubs found in warm climates, some species known for their characteristic thorns and nitrogen-fixing properties.

D. Insectivorous Plants

Insectivorous plants, also known as carnivorous plants, have fascinated botanists and nature enthusiasts with their unique adaptations to nutrient-poor environments. These remarkable plants have evolved various mechanisms to trap and digest insects and other small animals to obtain essential nutrients, particularly nitrogen and phosphorus. India, with its diverse climates and ecosystems, hosts a variety of insectivorous plants across its geography. Here's a brief overview of some notable insectivorous plants found in India:

Name	Feature, Location, and Insect Trapping Mechanism
Nepenthes	Modified leaves form pitcher-like structure trapping insects. Inner walls of pitcher are slippery, causing prey to fall into digestive fluid Found in Western Ghats, Northeastern India, Andaman Islands.

Name	Feature, Location, and Insect Trapping Mechanism
Drosera	Sticky, glandular hairs on leaves secrete dew-like substance trapping insects. Enzymes released by plants digest trapped insects. Widespread across India, especially Western Ghats, Eastern Himalayas.
Utricularia	Unique bladder-like traps submerged in water capture prey. Trapping mechanism involves suction of tiny aquatic organisms into bladders. Found in aquatic and semi-aquatic habitats across India, Western Ghats, Himalayas.
Pinguicula	Sticky, glandular leaves trap insects Leaves curl over trapped prey for digestion Less common, some species found in the Himalayas.
Aldrovanda	Rapid trap closures similar to submerged Venus Flytrap. Captures prey in aquatic habitats Rare, primarily found in aquatic habitats, reported in India.

These plants not only contribute to the fascinating biodiversity of India but also play a role in controlling insect populations and enriching the nutrient-poor soils in which they grow. The conservation of their habitats is crucial for their survival, as many carnivorous plants in India and around the world face threats from habitat destruction, pollution, and climate change.

E. Invasive Alien Plant Species

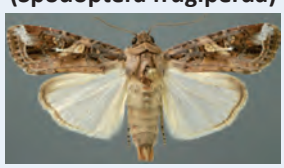
Invasive Alien Species are non-native organisms introduced into new environments, often by human activities, either accidentally or intentionally. Lacking natural predators in these new habitats, their populations can grow unchecked. These species can be plants, animals, pathogens, or parasites, and they threaten native biodiversity, ecosystems, and human activities.

❑ Invasion and Species Richness

- **Increased Species Richness:** Initially, invasions may increase local species richness by adding to the existing species pool.
- **Decreased Species Richness:** Over time, invasive species often outcompete native species for resources, leading to native species extinction and a net decrease in biodiversity.

Invasive Species	Native Place	Distribution in India	Info
Lantana camara	Central and South America	Widespread across many parts of India, particularly in forested areas	The Nilgiri Biosphere Reserve in the Western Ghats is heavily impacted by invasive species, Lantana Camara

Invasive Species	Native Place	Distribution in India	Info
Parthenium hysterophorus	Americas	Across India, especially problematic in agricultural lands	Often in news for its rapid spread and impact on crops
Prosopis juliflora	South America and the Caribbean	Arid and semi-arid regions(Aravali Hill region), including Rajasthan, Gujarat, and Tamil Nadu	
Water Hyacinth (Eichhornia crassipes)	Brazil	Water bodies across India, especially in Kerala, Assam, and West Bengal	Frequently in news for choking water bodies
Chromolaena odorata	Americas	Northeast India, Western Ghats, and other parts.	Known for its impact on biodiversity
Mikania micrantha	Central and South America	Northeast India, particularly in Assam and surrounding states	Referred to as “mile-a-minute weed”; often in news for its rapid growth
Ageratina adenophora	Mexico	Himalayan region, Northeast India	
Tithonia diversifolia	Central America	Spread in various parts of India, including the Western Ghats and Northeast India	Emerging invasive species, sometimes in news for its spread

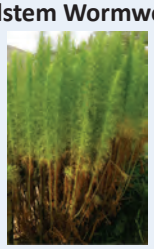
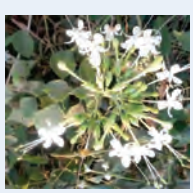
Invasive Species	Native Place	Distribution in India	Info
Argemone mexicana	Mexico and the Southwestern United States	Widespread in many parts, often found along roadsides and disturbed areas	Known as Mexican poppy; sometimes reported in agricultural news
Fall Armyworm (Spodoptera frugiperda) 	Tropical and subtropical regions of the Americas	Reported in several states affecting maize crops	Frequently in the news since its recent invasion causing significant crop damage

The introduction and spread of Invasive Alien Species constitute one of the greatest threats to global biodiversity, with significant and often irreversible impacts on native ecosystems. Effective management and conservation efforts are crucial to mitigate these impacts and protect native biodiversity.

F. Medicinal Plants

Medicinal plants play a significant role in traditional medicine systems across various regions, offering remedies for a wide array of ailments. Here are some notable examples:

Name	Region/Distribution in India	Uses
Meizotropis pellita	Uttarakhand	Essential oil from leaves has strong antioxidants, potential substitute for synthetic antioxidants in pharmaceuticals.
Fritillaria cirrhosa	Himalayan region	Used in China for treating bronchial disorders and pneumonia, cough suppressant, source of expectorant drugs.
Beddome's Cycad	Eastern Peninsular India	Treating rheumatoid arthritis and muscle pains, fire-resistant properties.
Kuth	Kashmir, Himachal Pradesh	Anti-inflammatory, used in traditional Tibetan medicine, perfumery, and as an insecticide.

Sarpagandha 	Sub Himalayan tract to Punjab, Nepal, Sikkim, Assam, Eastern & Western Ghats, Central India, Andamans	Medicinal roots used for CNS disorders contain reserpine for sedation and lowering blood pressure.
Cycads 	Western Ghats, Eastern Ghats, North East India, Andaman and Nicobar Islands	Used as a starch source and in socio-cultural rituals. Faces threats from over-harvesting and deforestation.
Elephant's Foot (Ponytail palm) 	Northwestern Himalayas	Commercial source of Diosgenin, used in synthesizing steroids like cortisone and progesterone.
Artemisia scoparia (Redstem Wormwood) 	Widespread in India	Clinical anti-malarial properties due to artemisinin; possesses potent anti-inflammatory properties.
Azadirachta indica (Neem) 	Across India	Used in traditional medicine; Neem bark and oil are known for immunostimulant properties.
Clerodendrum phlomidis (Sage Glory Bower, Arni, Agnimantha) 	Throughout India	Boosts the immune system, purifies blood, and cures urinary tract infections.
Physalis peruviana (Cape Gooseberry, Rasbhari) 	Cultivated and naturalized in various parts of India	Rich in vitamin C; used in traditional medicine as an immunomodulatory drug.

Withania somnifera (Indian Winter Cherry, Ashwagandha)	Widely cultivated and naturalized in India	Rejuvenating agent in Ayurveda with antioxidant, mind-boosting, and immune-enhancing properties.
Curcuma longa (Turmeric)	Found broadly throughout the Indian subcontinent.	Anti-inflammatory, antioxidant, potential benefits for neurodegenerative diseases and cancer
Withania somnifera- Ashwagandha	It grows in dry parts in sub-tropical regions. Rajasthan, Punjab, Haryana, Uttar Pradesh, Gujarat, Maharashtra and Madhya Pradesh, etc.	Adaptogenic (helps the body adapt to stress), possible benefits for anxiety, sleep, and cognitive function
Andrographis paniculata- Giloy	Endemic to India and is common throughout tropical and subtropical zones at an altitude of 600 m	Antiviral, immunomodulatory (boosts the immune system), potential benefits for respiratory infections
Emblica officinalis- Amla	Indigenous to Indian sub-continent. India ranks first in the world in area and production of this crop.	Rich in vitamin C, antioxidant, potential benefits for heart health and diabetes
Azadirachta indica- Neem	An evergreen tree found in the Indian subcontinent. It can grow and survive under a wide range of agro-climatic conditions.	Antibacterial, antifungal, potential benefits for skin conditions and wound healing

Medicinal plants across diverse regions of India offer a rich array of remedies for numerous health conditions, showcasing their integral role in traditional medicine. However, the sustainability of these valuable resources is threatened by over-harvesting, deforestation, and other environmental challenges, highlighting the need for conservation efforts to preserve their benefits for future generations.

IMPORTANT ENVIRONMENTAL PERSONALITIES

Category	Name	Notable Accomplishments
India	Sundarlal Bahuguna	Leader of the Chipko Movement (tree-hugging movement to protect forests)
India	Medha Patkar	Led the Narmada Bachao Andolan (movement against large dam projects)
India	Chandi Prasad Bhatt	Environmentalist known for his work in the Garhwal Himalayas, a founder of the Chipko Movement
India	Jadav Payeng	The "Forest Man of India" - single-handedly planted a forest over decades
India	Saalumarada Thimmakka	Environmentalist known for planting and tending to hundreds of banyan trees
India	Vandana Shiva	Scholar, environmental activist, anti-globalization author. Focused on biodiversity and opposition to GMOs
India	Winona LaDuke	Anishinaabekwe (Ojibwe) environmentalist, economist, and writer. Known for her work on tribal land claims and preservation
World	Wangari Maathai (Kenya)	Founder of the Green Belt Movement, focusing on tree planting, women's rights, and environmental conservation. Nobel Peace Prize Laureate.
World	Rachel Carson (USA)	Marine biologist, author of "Silent Spring," which catalyzed the modern environmental movement
World	Greta Thunberg (Sweden)	Young climate activist inspiring global action through "Fridays for Future" school strikes
World	Chico Mendes (Brazil)	Rubber tapper and union leader, fought to preserve the Amazon rainforest. Assassinated for his activism.
World	Jane Goodall (UK)	Primatologist, ethologist, anthropologist, and conservationist known for her ground-breaking work with chimpanzees

IMPORTANT ENVIRONMENTAL AWARDS & THEIR WINNERS

Award	Description	Winner(s)
Goldman Environmental Prize, 2023	Honors grassroots environmental activists from six geographic regions of the world (Africa, Asia, Europe, Islands & Island Nations, North America, and South & Central America)	Alessandra Korap Munduruku (Brazil), Chilekwa Mumba (Zambia), Delima Silalahi (Indonesia), Diane Wilson (United States), Tero Mustonen (Finland), Zafer Kizilkaya (Turkey)
Champions of the Earth, 2023	Awarded annually by the United Nations Environment Programme (UNEP) to recognize outstanding leadership and achievements in environmental protection	Josefina Belmonte Belmonte, mayor of Quezon City in the Philippines (Policy Leadership), the UK-based Ellen MacArthur Foundation (Inspiration and Action), China's Blue Circle (Entrepreneurial Vision), José Manuel Moller of Chile (Entrepreneurial Vision) and Council for Scientific and Industrial Research (Science and Innovation) were declared winners "for their innovative solutions and transformative action to tackle plastic pollution".
The Earthshot Prize, 2023	Recognizes and rewards five individuals or teams for their groundbreaking work towards repairing and regenerating the planet	Acción Andina, GRST, WildAid Marine Program, S4S Technologies, and Boomitra
Right Livelihood Award	Often referred to as the "Alternative Nobel Prize," honors individuals and organizations for their outstanding work on global issues	Eunice Brookman-Amissah (Ghana), Mother Nature Cambodia, SOS MEDITERRANEE, and Phyllis Omido (Kenya)
UNEP Sasakawa Prize, 2022	Awarded every two years to individuals or institutions for their outstanding leadership and contribution to the environment and sustainable development	Three individuals – Myriam Urzúa Venegas, Rajib Shaw and Glenn Suerte Felipe Banaguas – and three organizations – the Pacific Disaster Center, Save the Children Philippines, and SEEDS.

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